Visual Analytics & Learning Analytics in support of **Data-Driven Decision Making**

Katy Börner, Indiana University @katycns

SFI Colloquium on "The Complexity of Educational Ecosystems"
Santa Fe Institute, Santa Fe, New Mexico

June 4, 2018

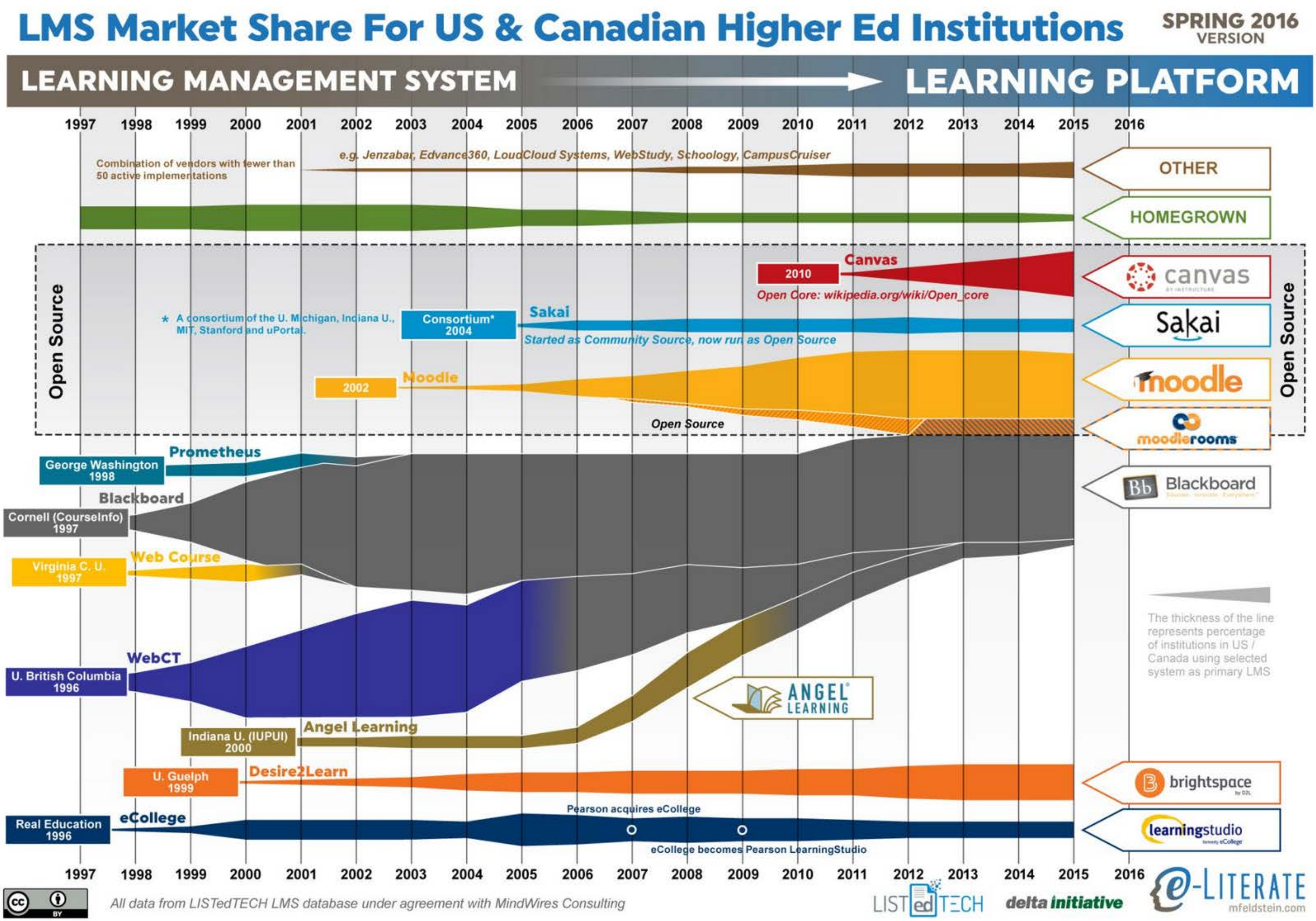
Visual Analytics & Learning Analytics in support of Data-Driven Decision Making

Outline:

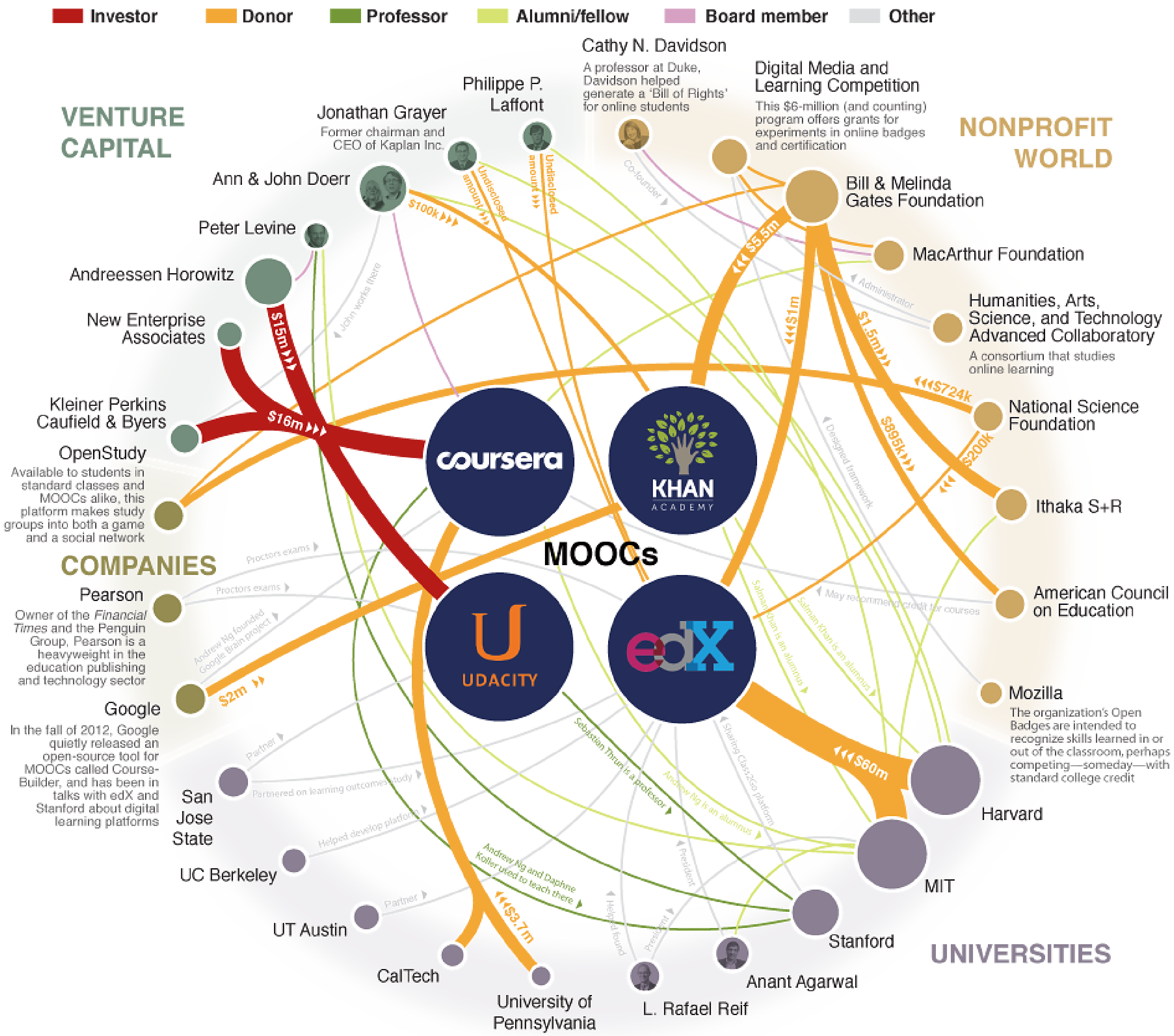
Context
Data Driven Decision Making
Visual Analytics
Learning Analytics

Embracing Human and Machine Intelligence Symbiosis

Context



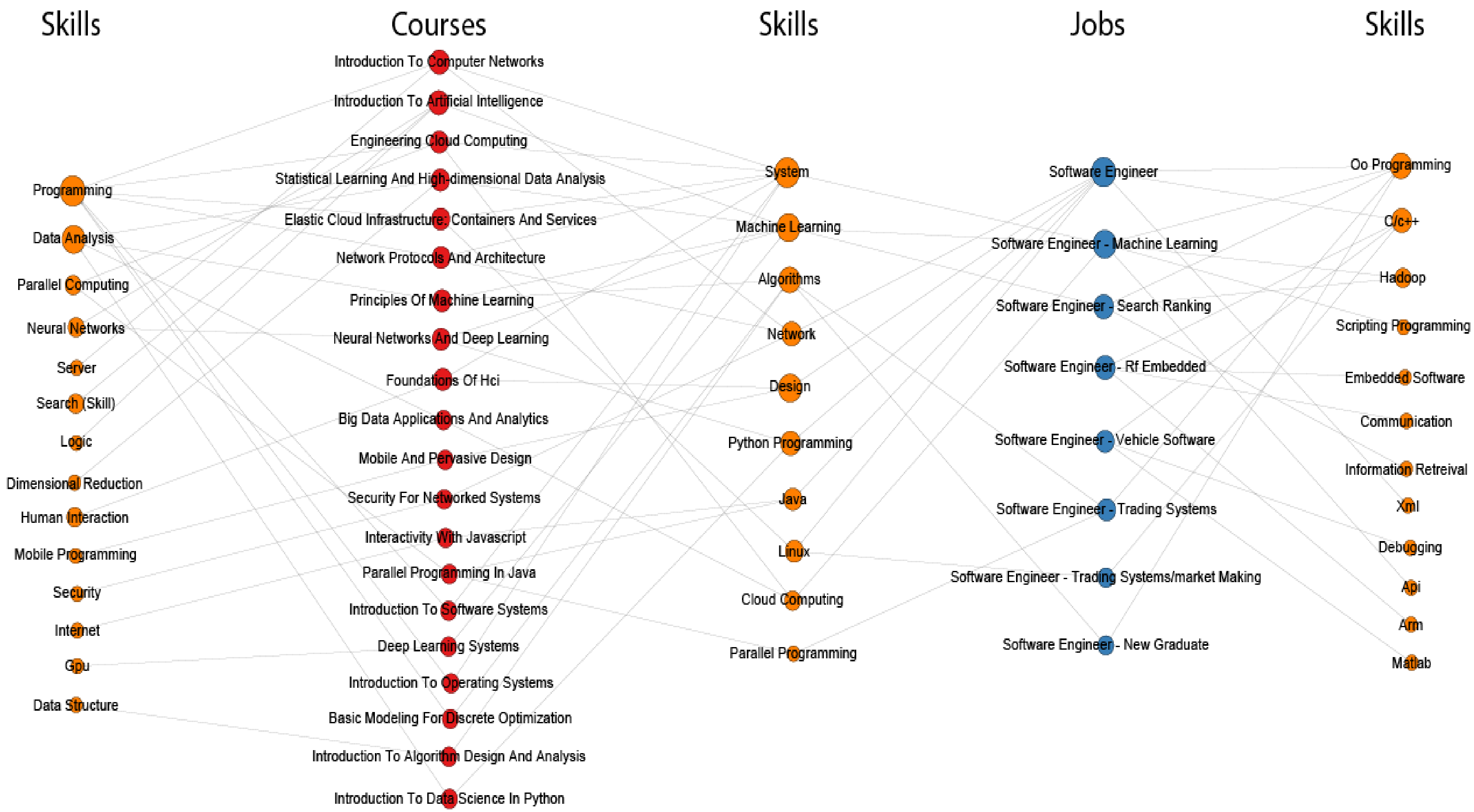
https://mfeldstein.com/state-higher-ed-lms-market-spring-2016



https://www.chronicle.com/article/Major-Players-in-the-MOOC/138817 - April 29, 2013

IU Data Science Program: Courses, Skills & Jobs

Katy Börner, Michael Ginda & Xiaozhong Liu, Indiana University

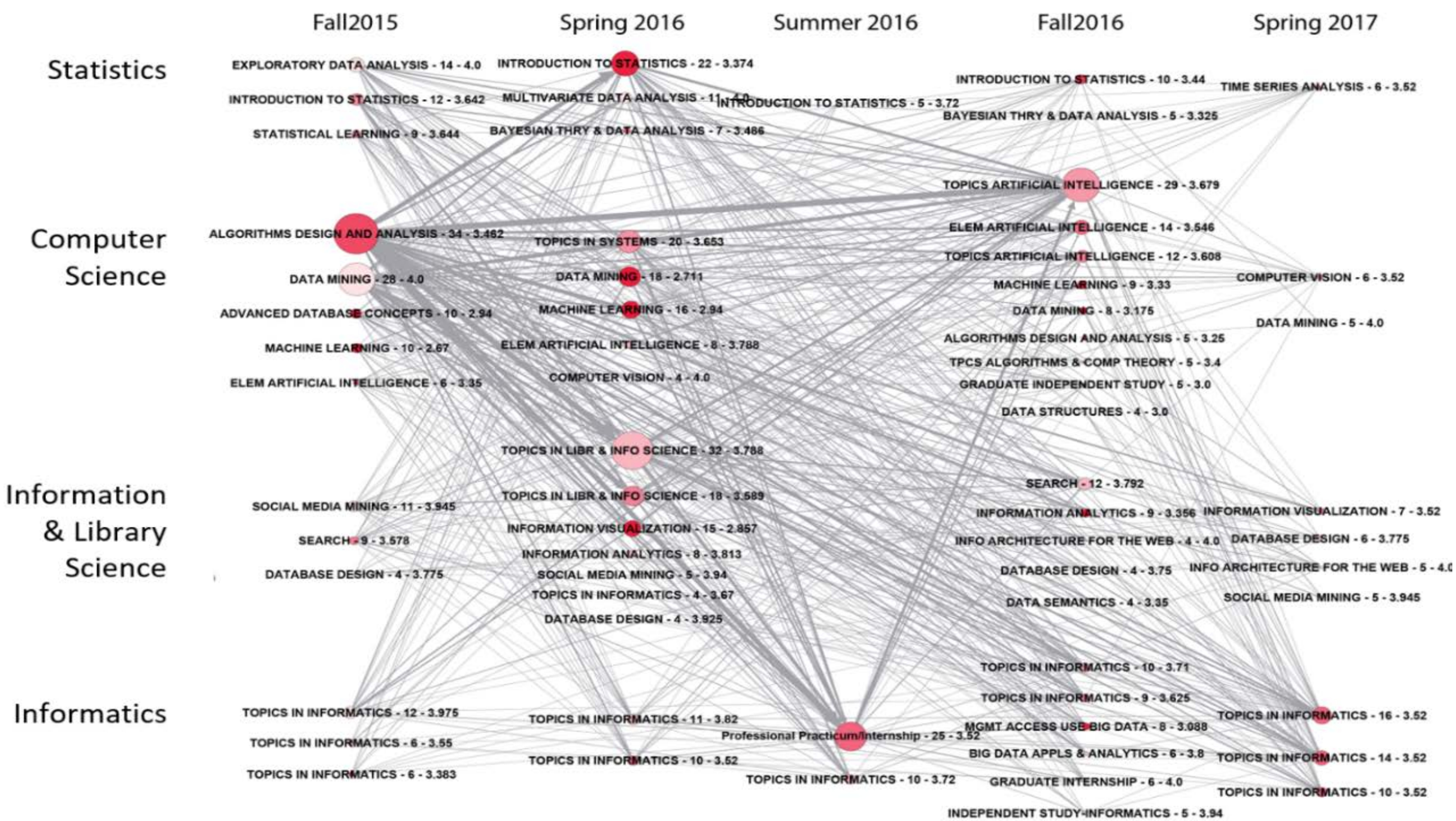


Exemplary set of IU Data Science courses, 'Software Engineering' jobs, and associated skills.

Job data was retrieved from LinkedIn and CareerBuilder and course data come from the IU course list. As can be seen, there are many skills (in orange) that are exclusively associated with courses or jobs; however, the skills in the middle interlink courses (in red) to jobs (in blue).

IU Data Science Program: Student Course Transition Network

Michael Ginda, Kayla Scroggins & Katy Börner, Indiana University



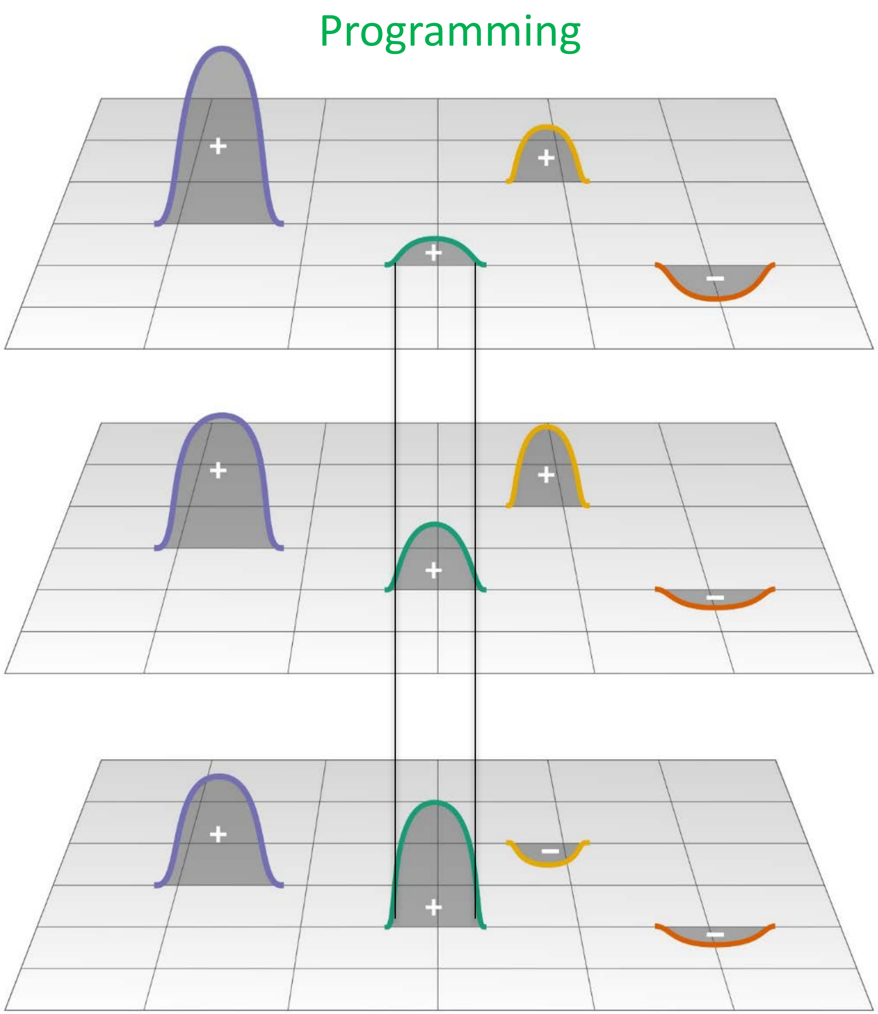
Empower students, teachers, and curriculum committee members to understand and discuss current and desirable student cohorts, key course trajectories, or the (gatekeeper) role that specific courses play.

Vertically, courses are arranged into four groups based on the department offering the course. Within each vertical grouping, the nodes are sorted by the total enrollment for the course with highest values on top. Node size encodes number of students enrolled; node color denotes overall GPA for the course.

Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.



Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size

Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

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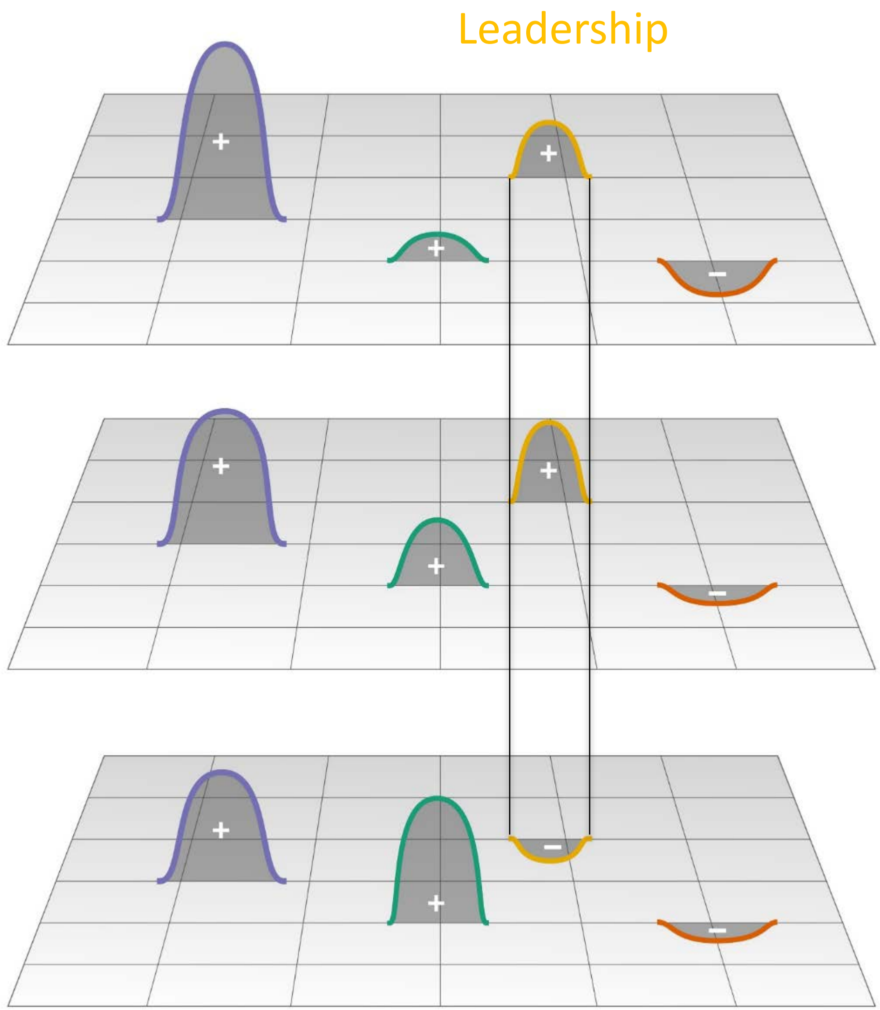

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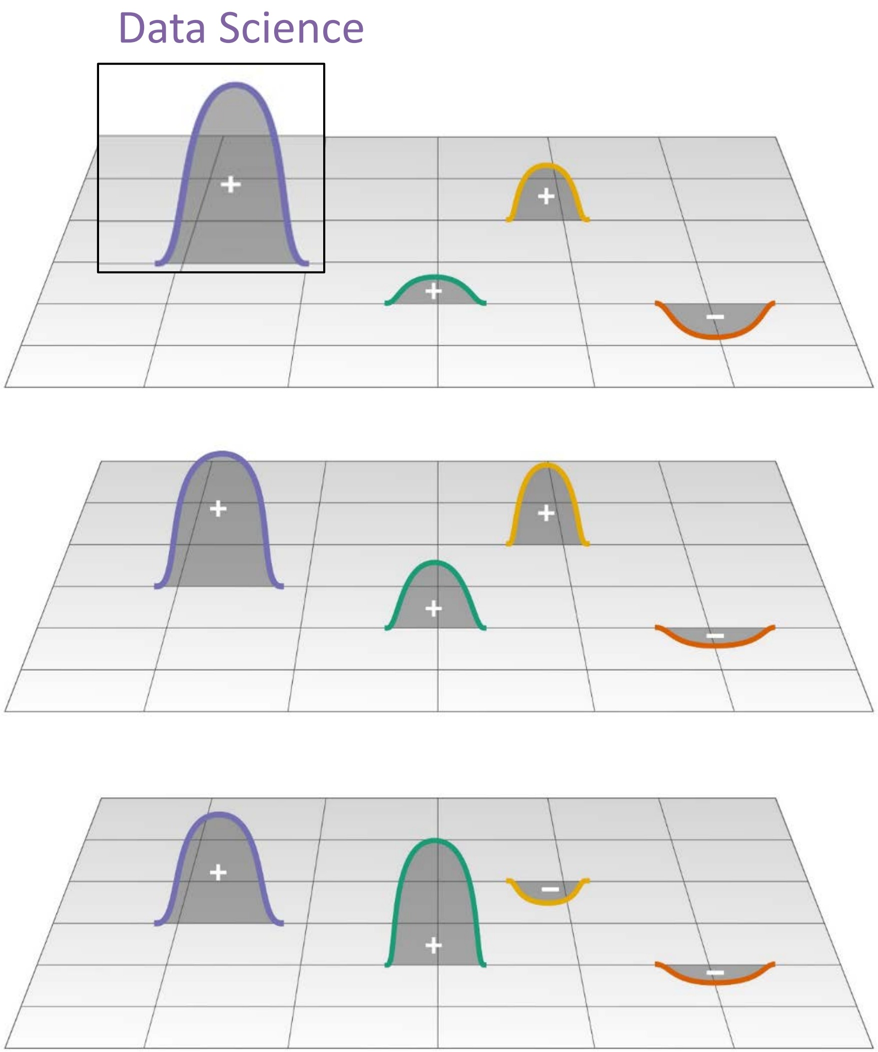

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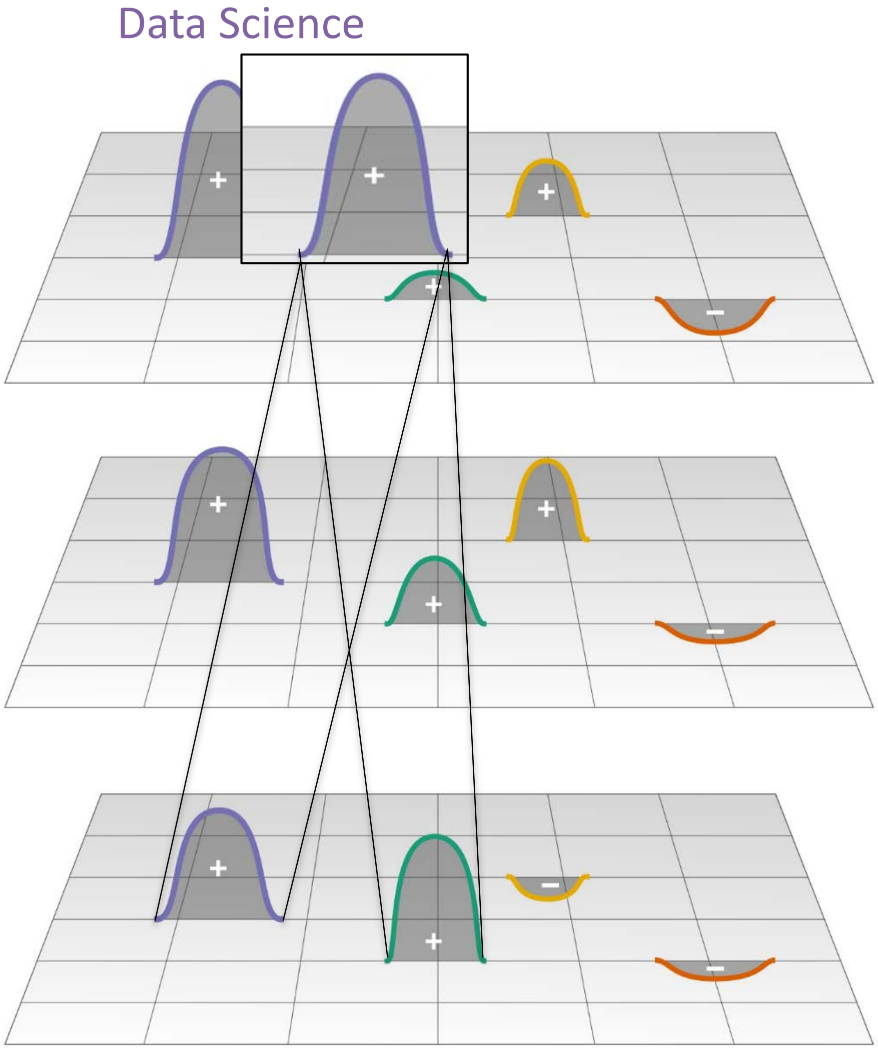

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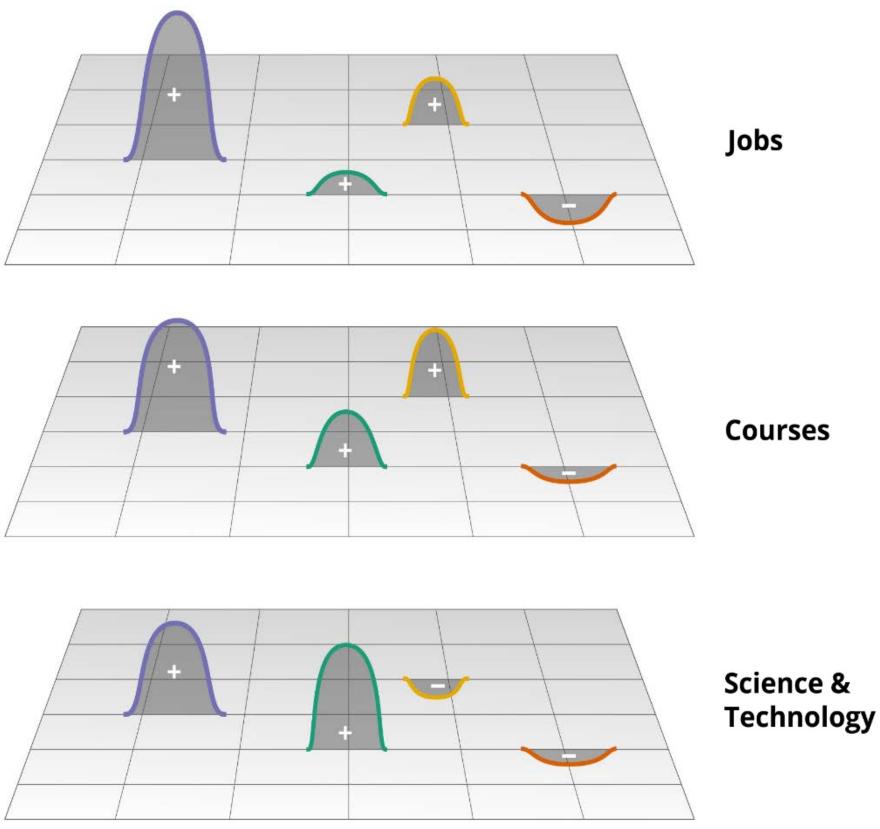
Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Study results are needed by:

- **Students:** What jobs will exist in 1-4 years? What program/learning trajectory is best to get/keep my dream job?
- **Teachers:** What course updates are needed? What curriculum design is best? What is my competition doing? How much timely knowledge (to get a job) vs. forever knowledge (to be prepared for 80 productive years) should I teach? How to innovate in teaching and get tenure?
- **Employers:** What skills are needed next year, in 5 years? Who trains the best? What skills does my competition list in job advertisements? How to hire/train productive teams?



What is ROI of my time, money, compassion?

#SacklerModVisST

Arthur M. Sackler COLLOQUIA OF THE NATIONAL ACADEMY OF SCIENCES

Modeling and Visualizing Science and Technology Developments

National Academy of Sciences Sackler Colloquium, December 4-5, 2017, Irvine, CA

Rankings and the Efficiency of Institutions

H. Eugene Stanley | Albert-László Barabási | Lada Adamic | Marta González | Kaye Husbands Fealing | Brian Uzzi | John V. Lombardi

Higher Education and the Science & Technology Job Market

Katy Börner | Wendy L. Martinez | Michael Richey | William Rouse | Stasa Milojevic | Rob Rubin | David Krakauer

Innovation Diffusion and Technology Adoption

William Rouse | Donna Cox | Jeff Alstott | Ben Shneiderman | Rahul C. Basole | Scott Stern | Cesar Hidalgo

Modeling Needs, Infrastructures, Standards

Paul Trunfio | Sallie Keller | Andrew L. Russell | Guru Madhavan | Azer Bestavros | Jason Owen-Smith

nasonline.org/Sackler-Visualizing-Science

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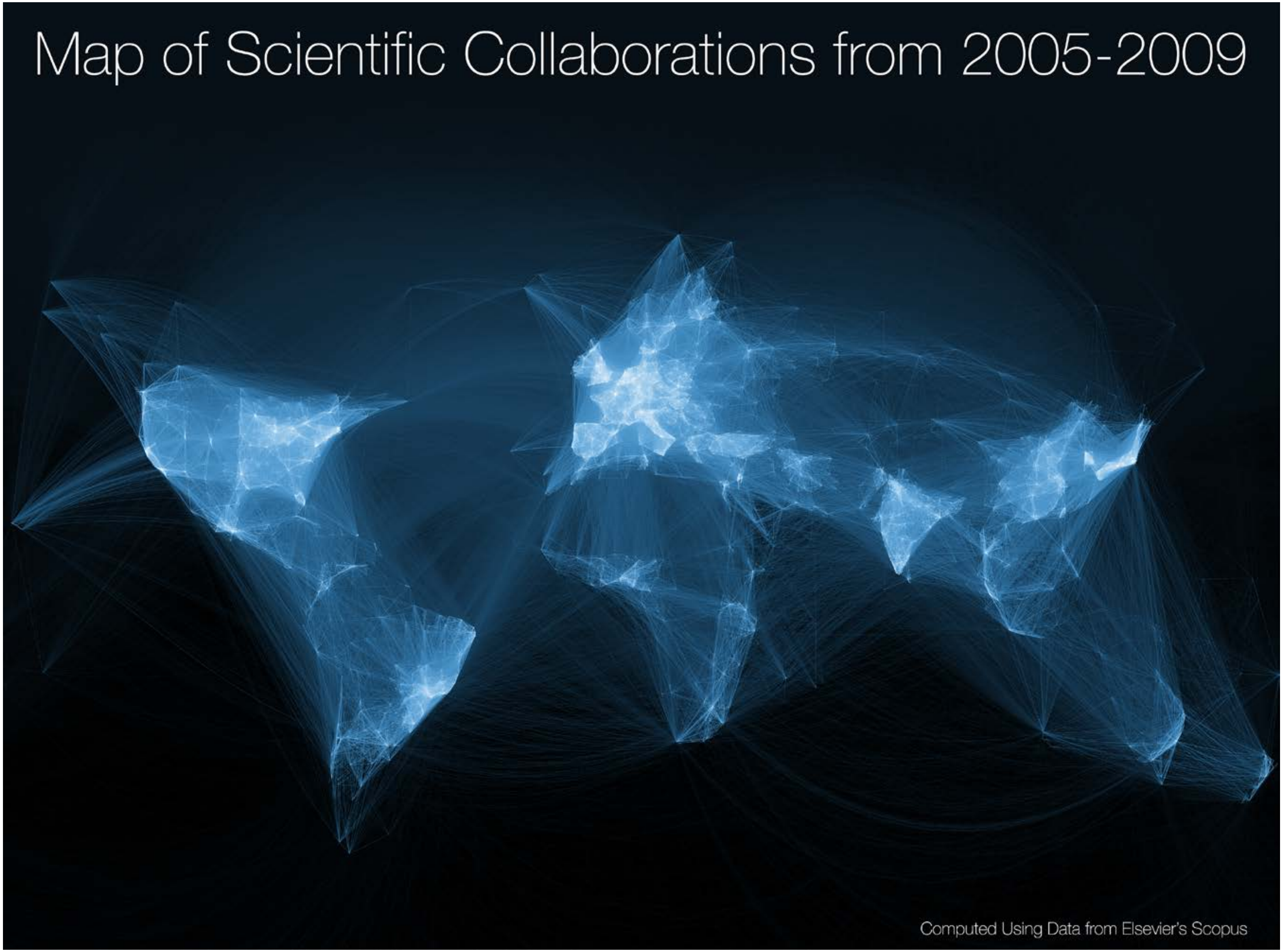
Clarivate

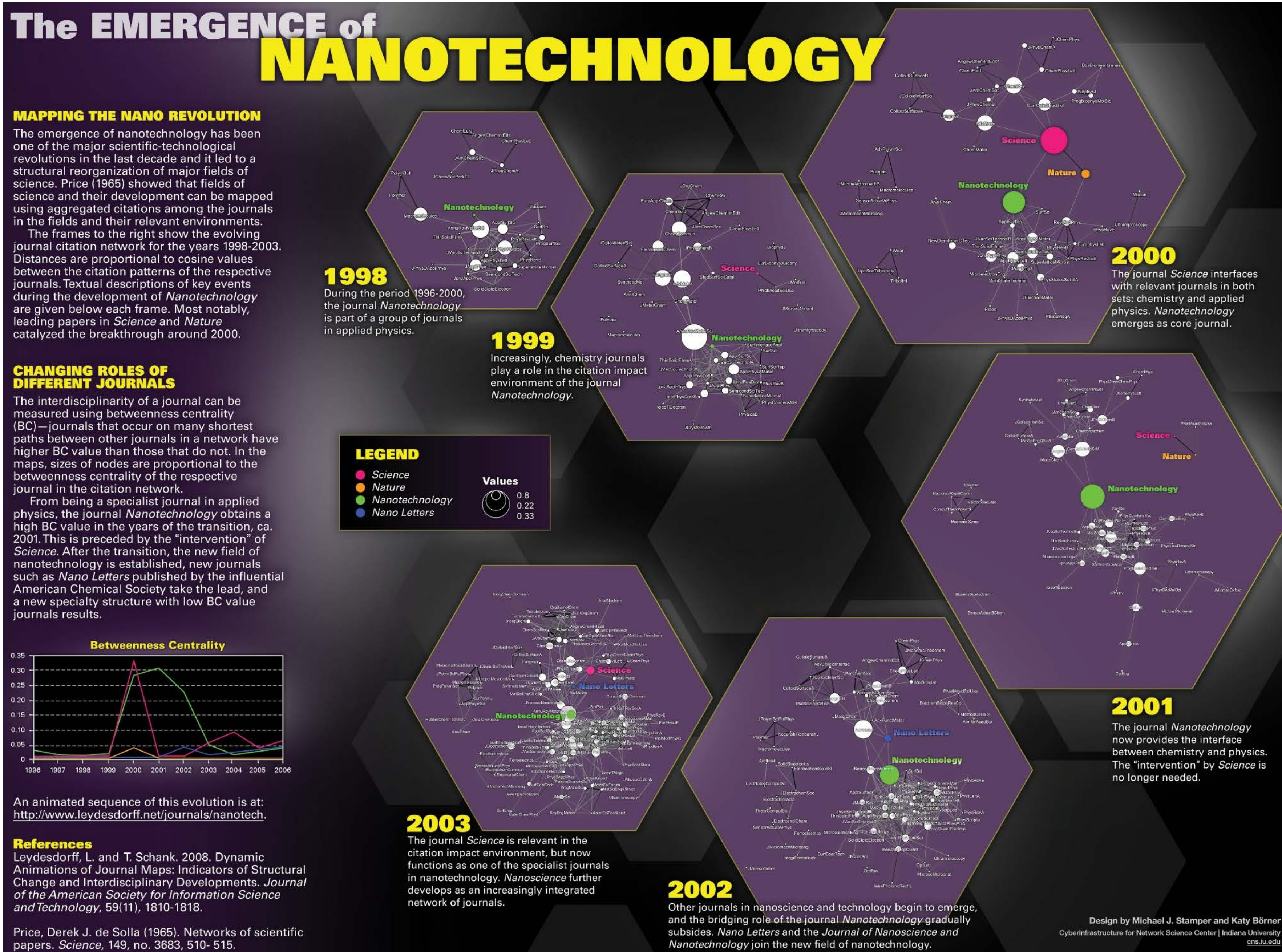
Microsoft

Data Driven Decision Making

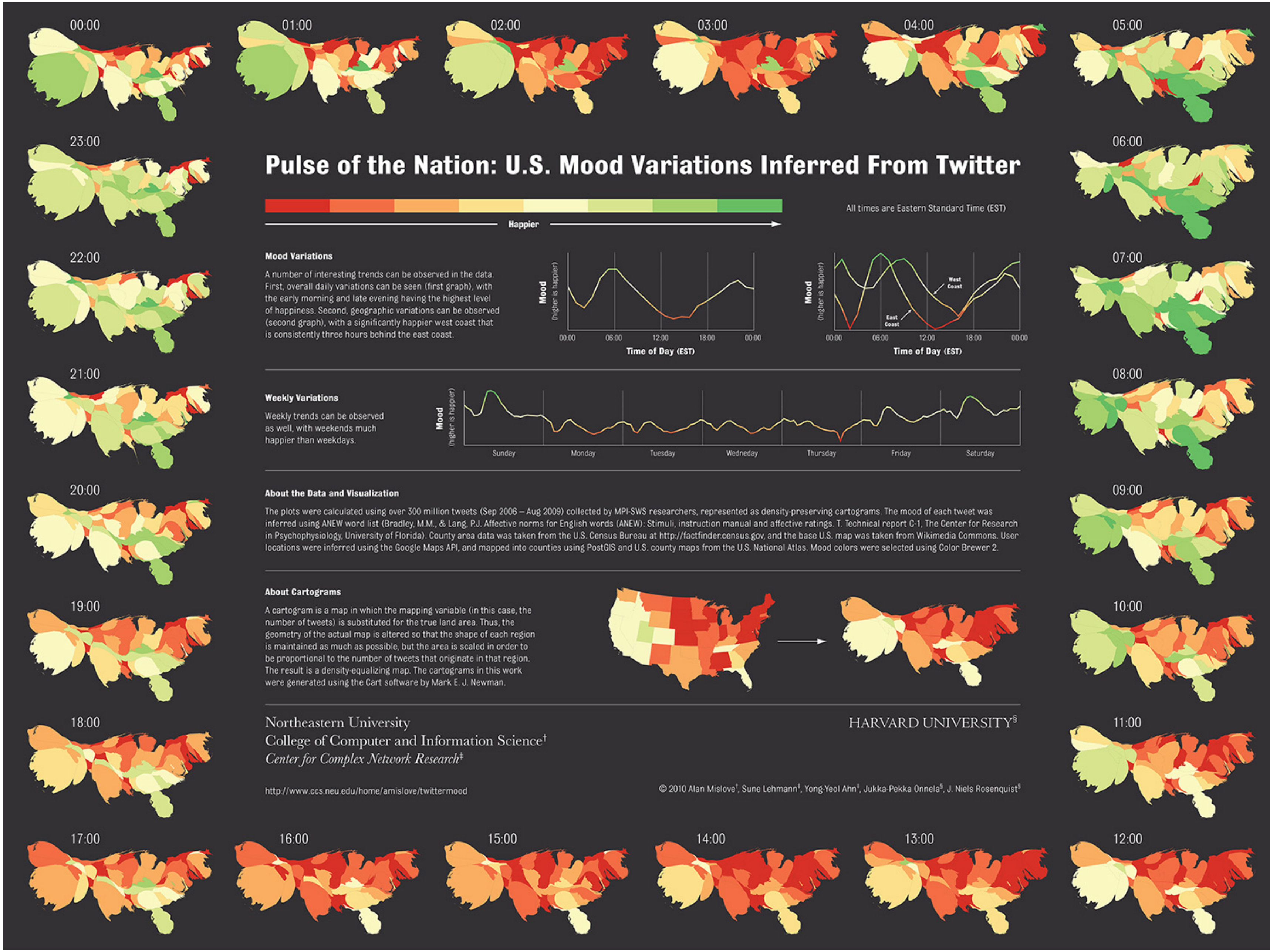
III.5 *Science & Technology Outlook: 2005-2055* – Marina Gorbis, Jean Hagan, Alex Soojung-Kim Pang, and David Pescovitz - 2006



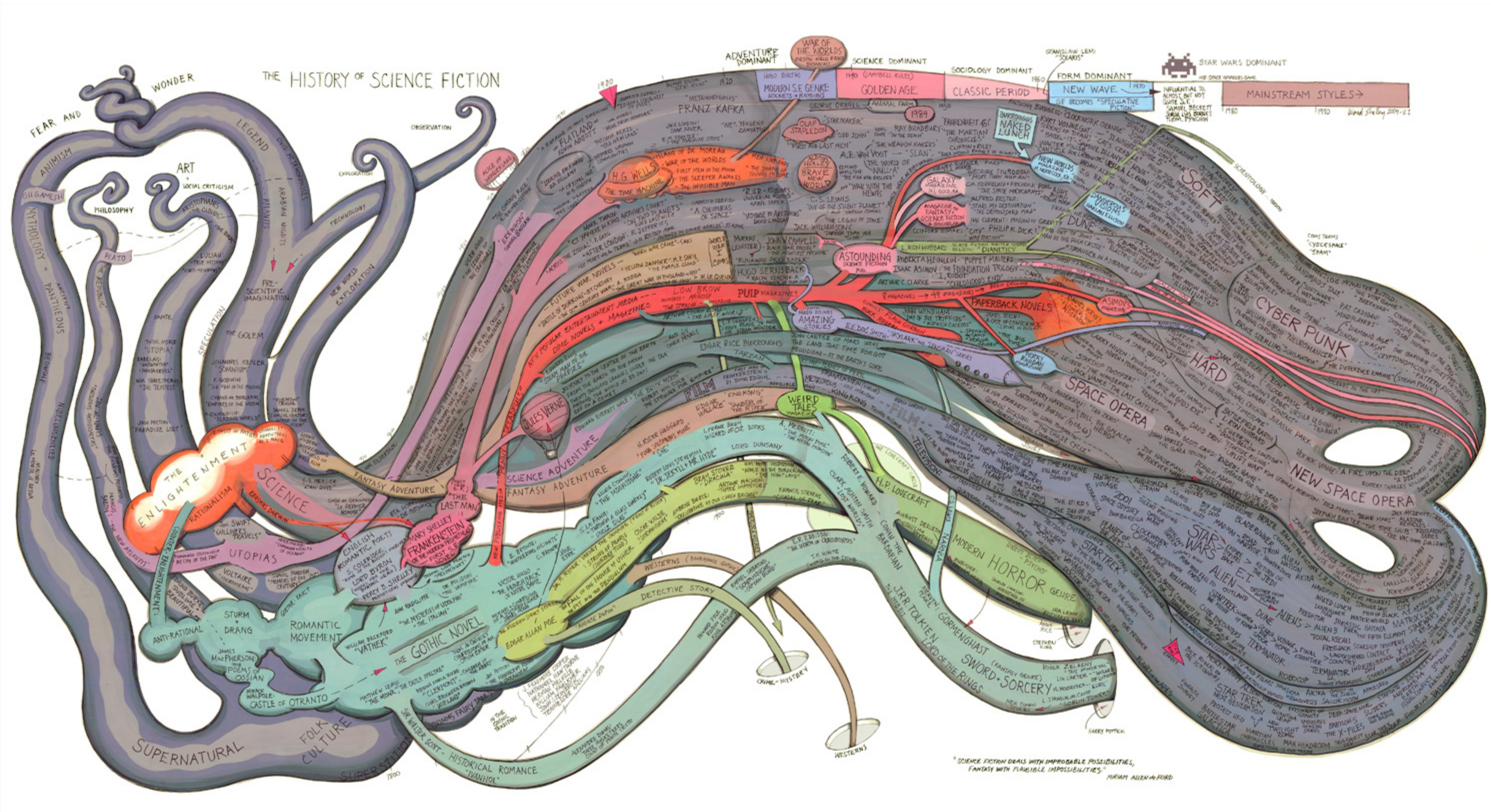
Stream of Scientific Collaborations Between World Cities - Olivier H. Beauchesne - 2012



VI.8 *The Emergence of Nanoscience & Technology* - Loet Leydesdorff - 2010

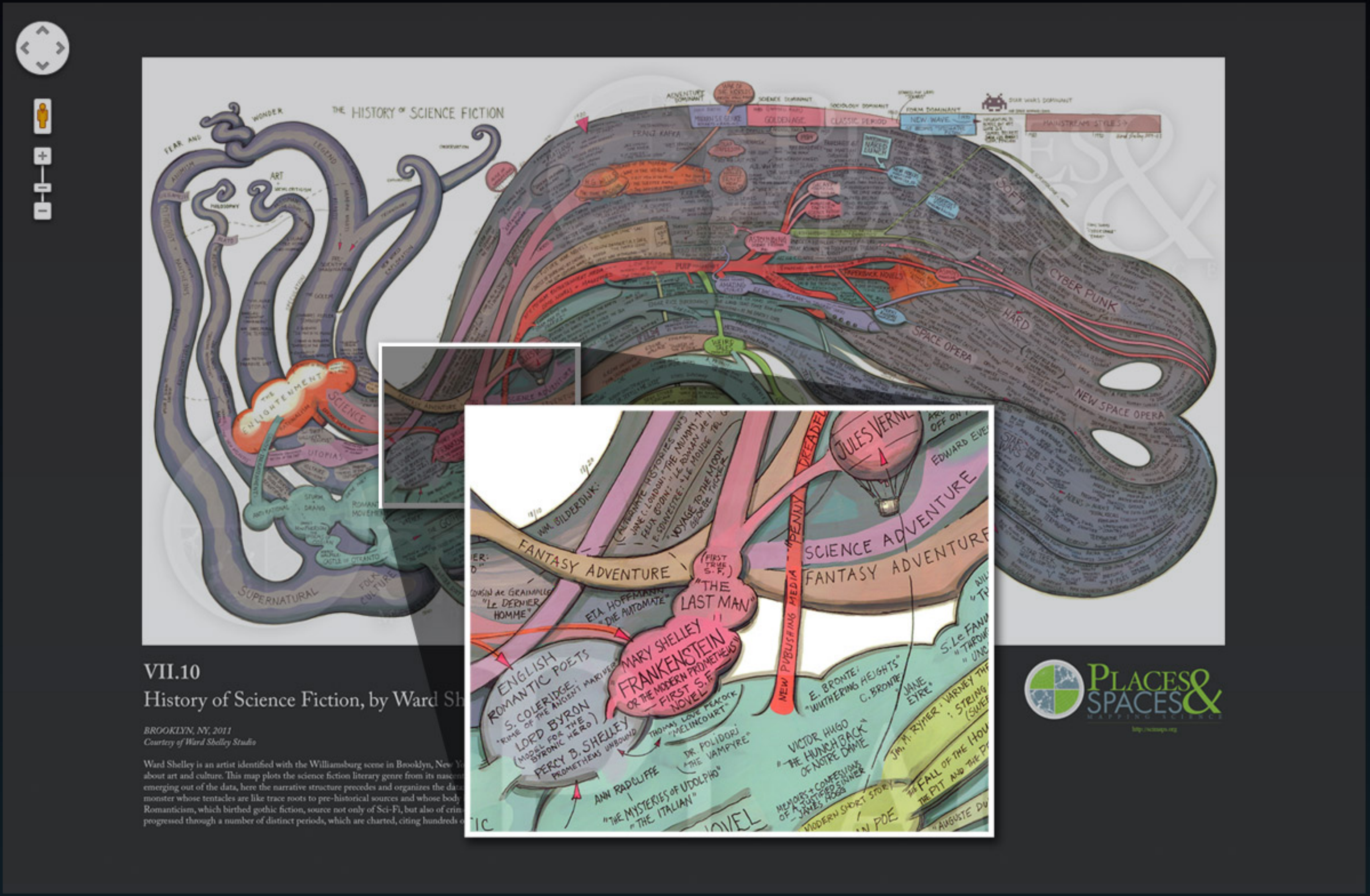


IX.4 *Pulse of the Nation* - Alan Mislove, Sune Lehmann, Yong-Yeol Ahn, Jukka-Pekka Onnela, and James Niels Rosenquist - 2010

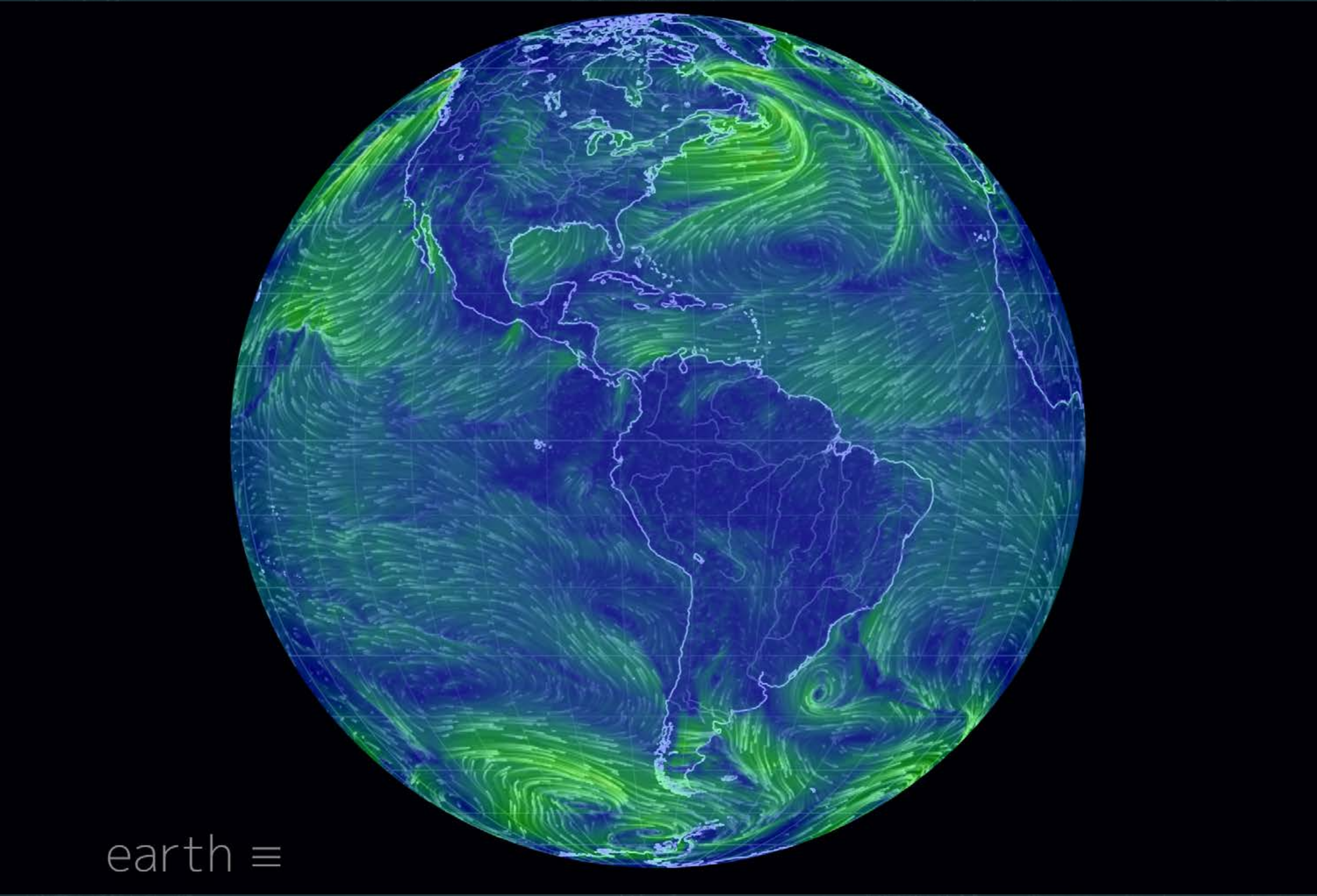


VII.10 *History of Science Fiction* - Ward Shelley - 2011

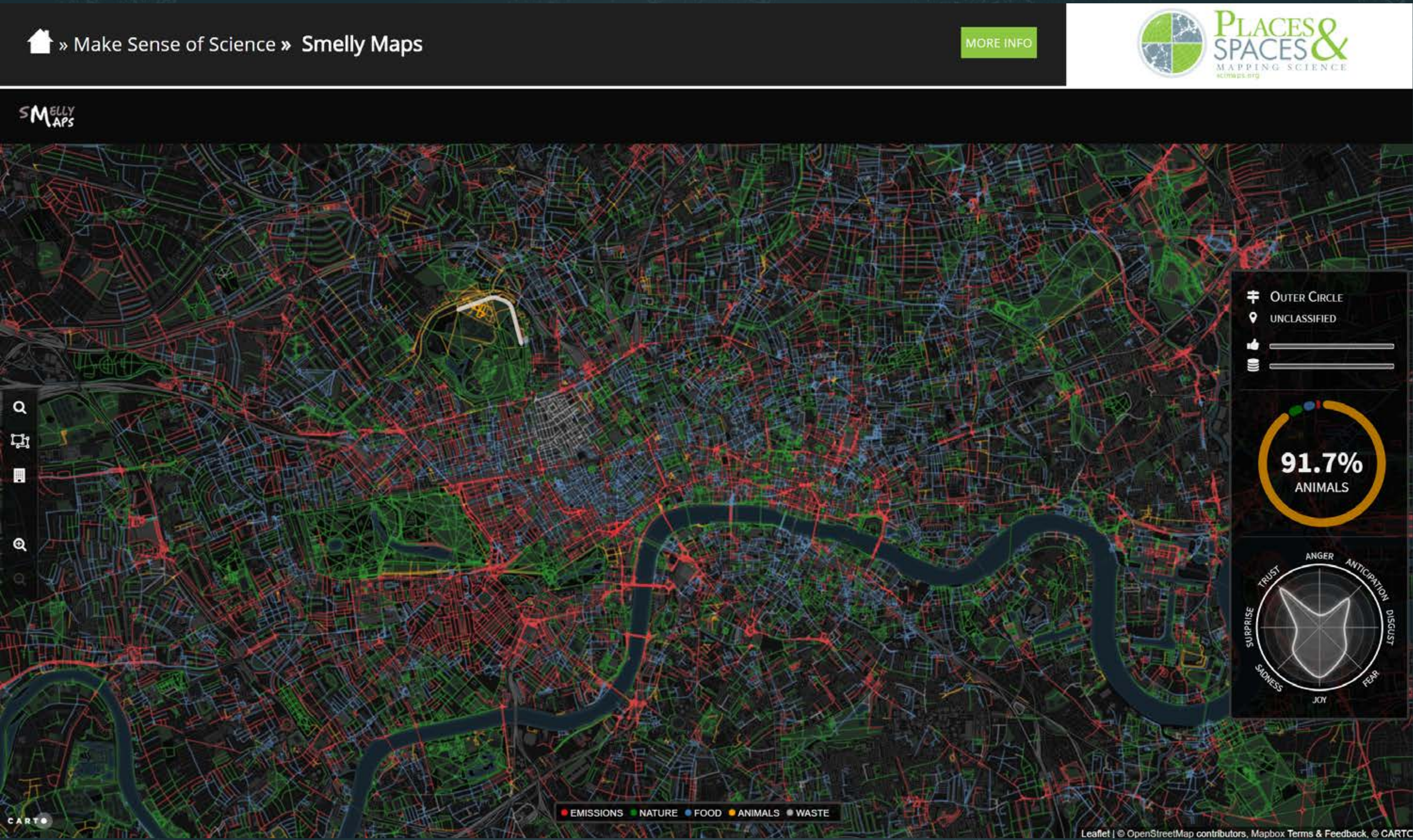
Check out our Zoom Maps online!



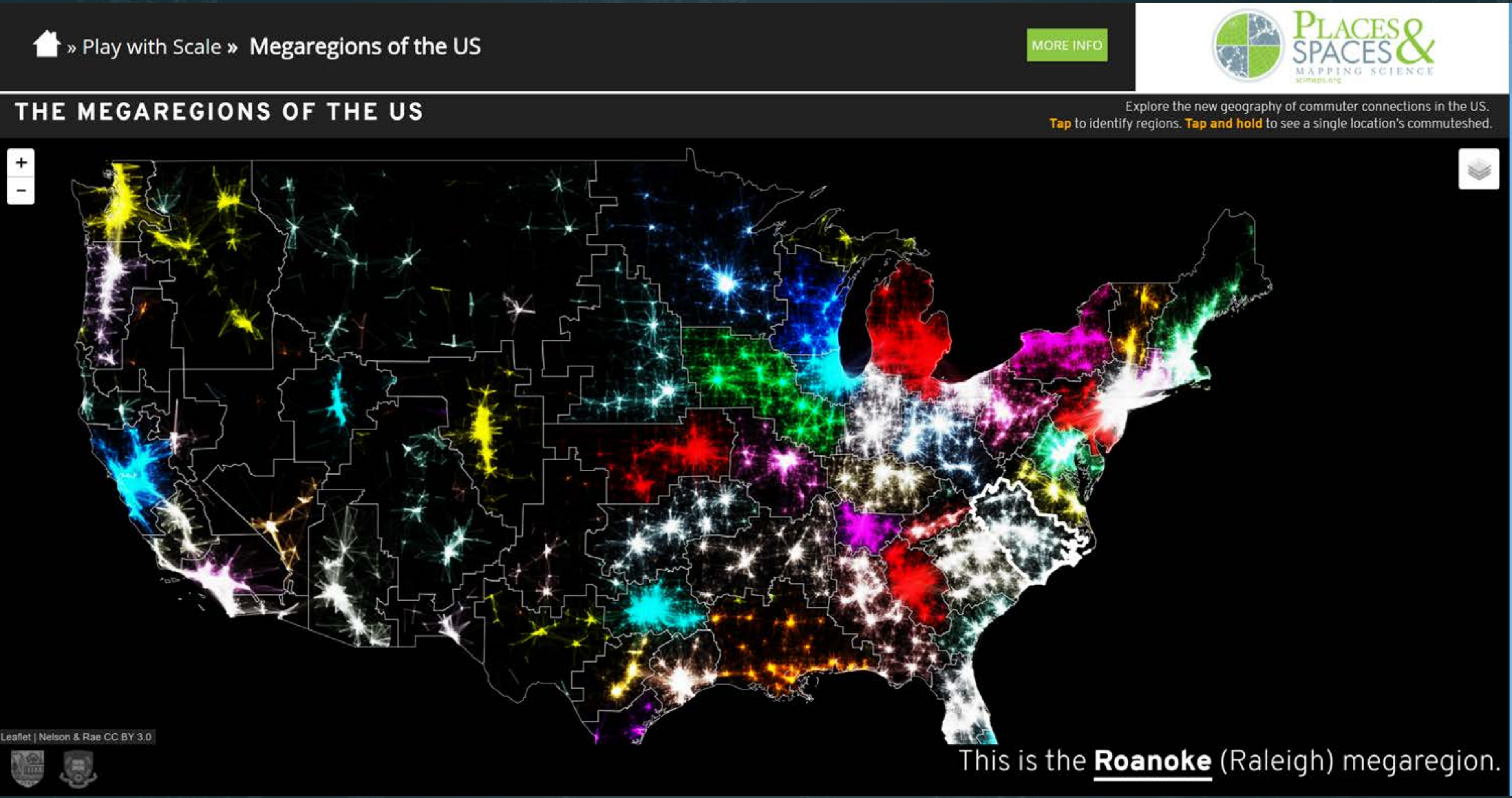
Visit scimaps.org and check out all our maps in stunning detail!



Earth – Cameron Beccario



Smelly Maps – Daniele Quercia, Rossano Schifanella, and Luca Maria Aiello – 2015



Megaregions of the US –Garrett Dash Nelson and Alasdair Rae – 2016

Visual Analytics - IVMOOC

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Data Visualization Literacy

Data visualization literacy (ability to read, make, and explain data visualizations) requires

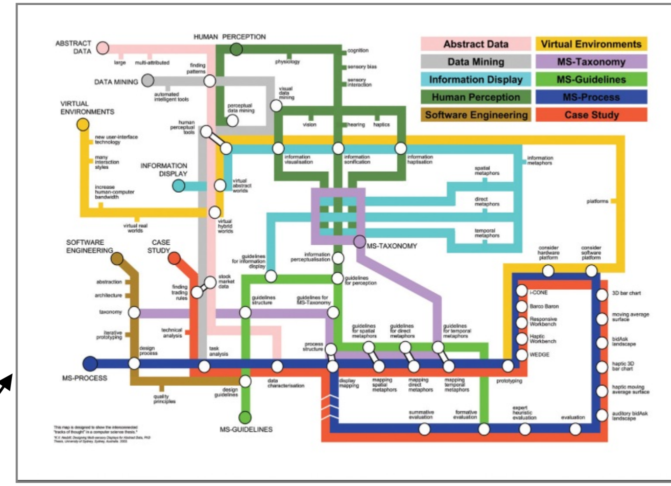
- *literacy* (ability to read and write text, e.g., in titles, axis labels, legend),
- *visual literacy* (ability to find, interpret, evaluate, use, and create images and visual media), and
- *data literacy* (ability to read, create, and communicate data).

Being able to “read and write” data visualizations is becoming as important as being able to read and write text. Understanding, measuring, and improving data and visualization literacy is important for understanding STEAM developments and to strategically approach global issues.

Different Question Types

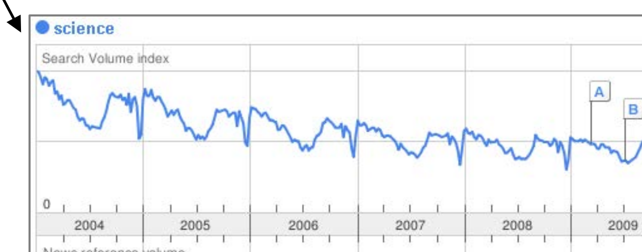
Terabytes of data

Descriptive & Predictive Models



Find your way

Find collaborators, friends

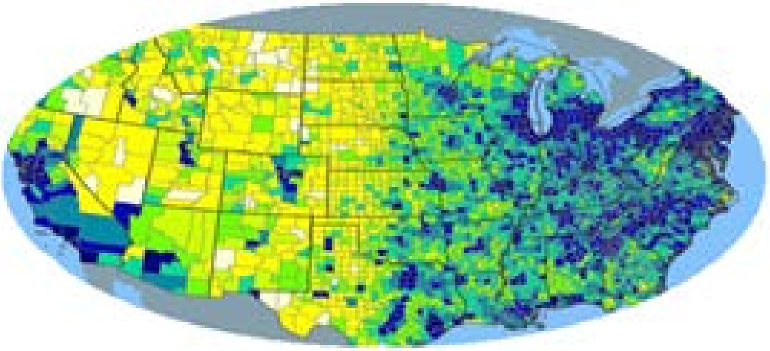


Identify trends

Different Levels of Abstraction/Analysis

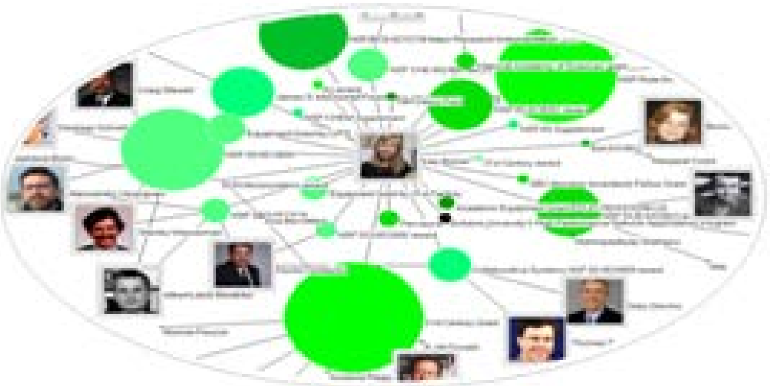
Macro/Global

Population Level



Meso/Local

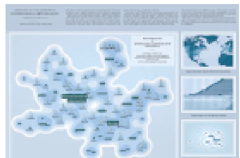
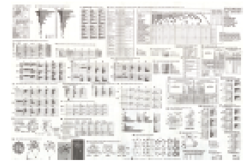
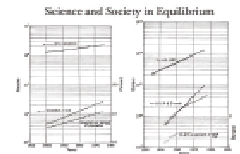
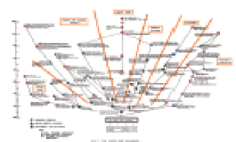
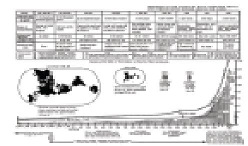
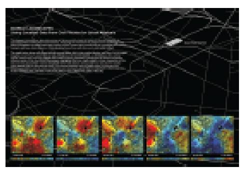
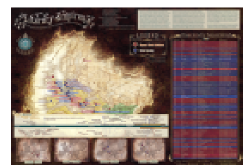
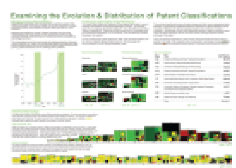
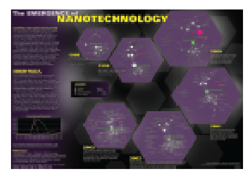
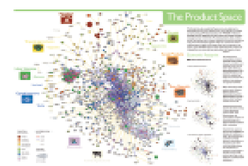
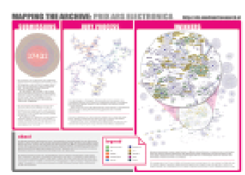
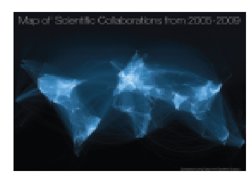
Group Level

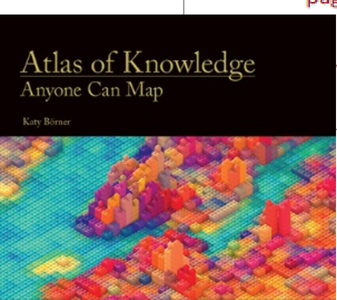


Micro

Individual Level

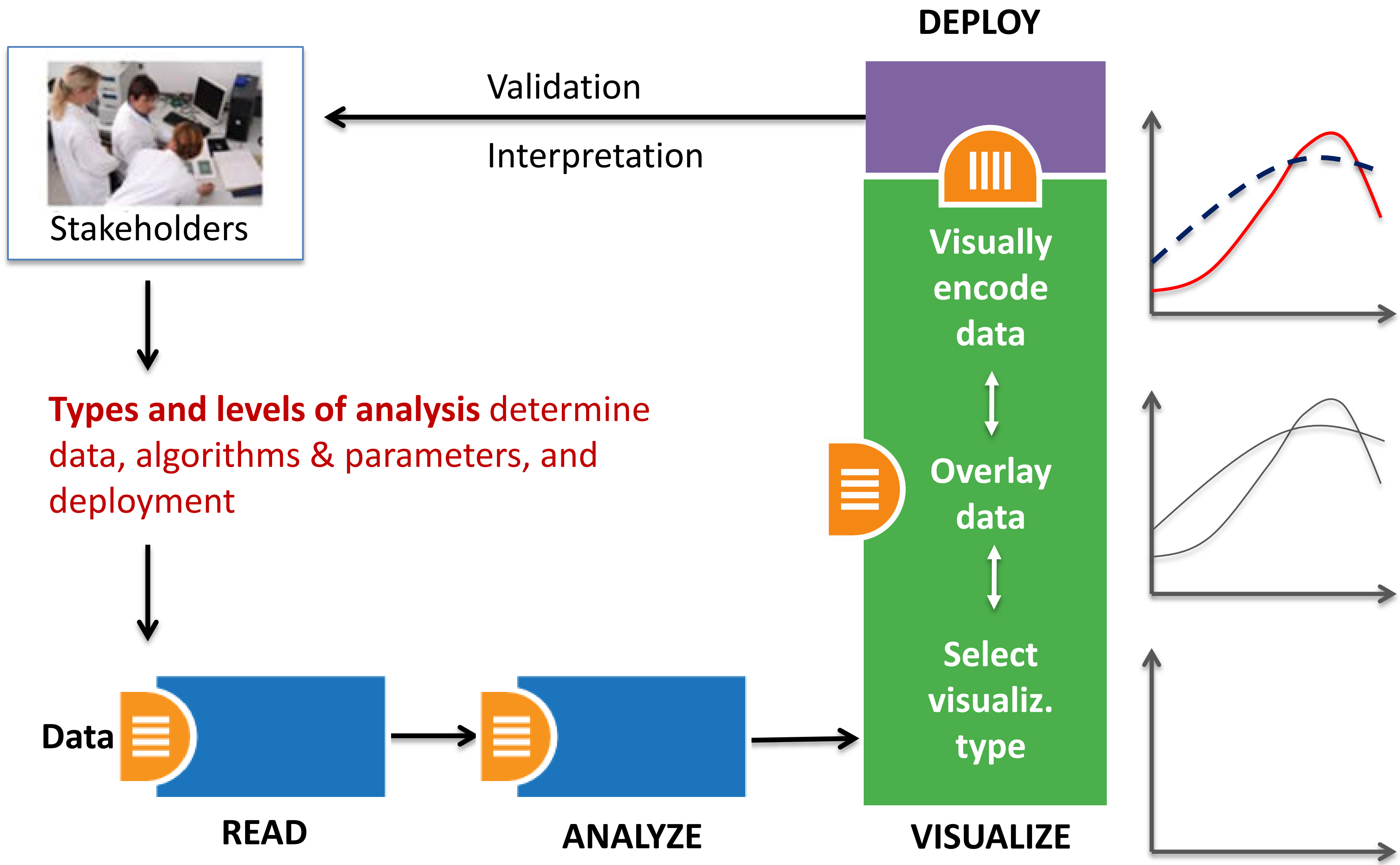
Tasks

TYPES \ LEVELS	MICRO: Individual Level about 1–1,000 records page 6	MESO: Local Level about 1,001–100,000 records page 8	MACRO: Global Level more than 100,000 records page 10
Statistical Analysis page 44	 Knowledge Cartography page 135	 Productivity of Russian life sciences research teams page 105	 Number of scientists versus population and R&D costs versus GNP. page 103
WHEN: Temporal Analysis page 48	 Visualizing decision-making processes page 95	 Key events in the development of the video tape recorder page 85	 Increased travel and communication speeds page 83
WHERE: Geospatial Analysis page 52	 Cell phone usage in Milan, Italy page 109	 Victorian poetry in Europe page 137	 Ecological footprint of countries page 99
WHAT: Topical Analysis page 56	 Evolving patent holdings of Apple Computer, Inc. and Jerome Lemelson page 89	 Evolving journal networks in nanotechnology page 139	 Product space showing co-export patterns of countries page 93
WITH WHOM: Network Analysis page 60	 World Finance Corporation network page 87	 Electronic and new media art networks page 133	 World-wide scholarly collaboration networks page 157

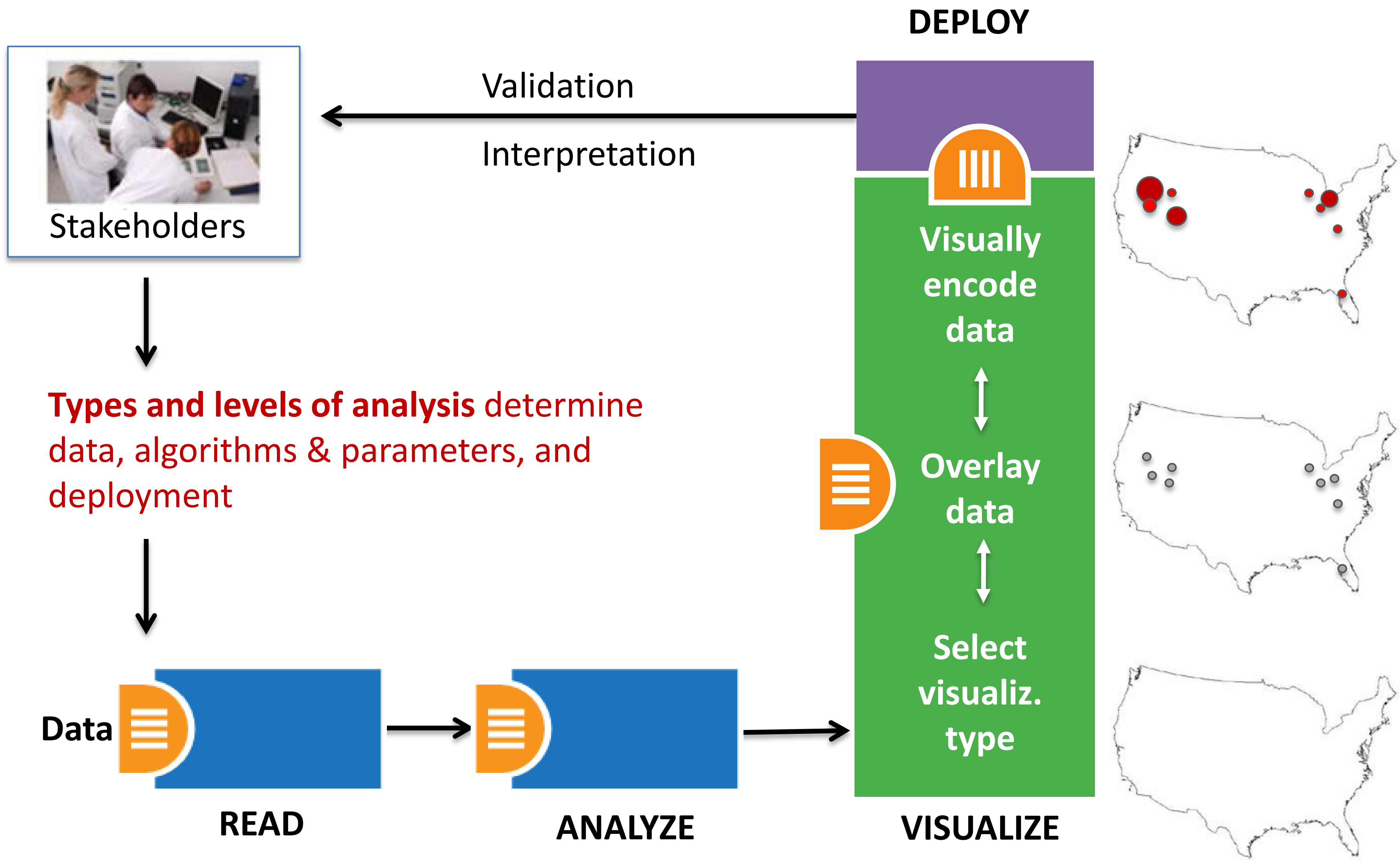


See *Atlas of Science: Anyone Can Map*, page 5

Needs-Driven Workflow Design

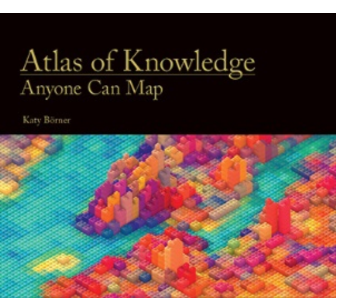


Needs-Driven Workflow Design



Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
• categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships	• nominal • ordinal • interval • ratio	• table • chart • graph • map • network layout	• geometric symbols point line area surface volume • linguistic symbols text numerals punctuation marks • pictorial symbols images icons statistical glyphs	• spatial position • retinal form color optics motion	• overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion



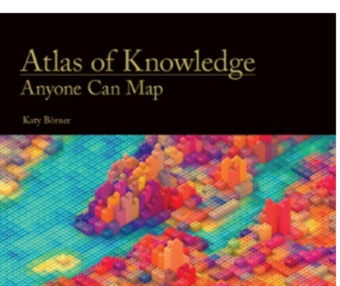
See *Atlas of Science: Anyone Can Map*, page 24

Visualization Framework

Basic Task Types								
Bertin, 1967	**Wehrend & Lewis, 1996**	**Few, 2004**	**Yau, 2011**	**Rendgen & Wiedemann, 2012**	**Frankel, 2012**	**Tool: Many Eyes**	**Tool: Chart Chooser**	**Börner, 2014**
selection	categorize			category				categorize/ cluster
order	rank	ranking					table	order/rank/ sort
	distribution	distribution					distribution	distributions (also outliers, gaps)
	compare	nominal comparison & deviation	differences		compare and contrast	compare data values	comparison	comparisons
		time series	patterns over time	time	process and time	track rises and falls over time	trend	trends (process and time)
		geospatial	spatial relations	location		generate maps		geospatial
quantity		part-to-whole	proportions		form and structure	see parts of whole, analyze text	composition	compositions (also of text)
association	correlate	correlation	relationships	hierarchy		relations between data points	relationship	correlations/ relationships

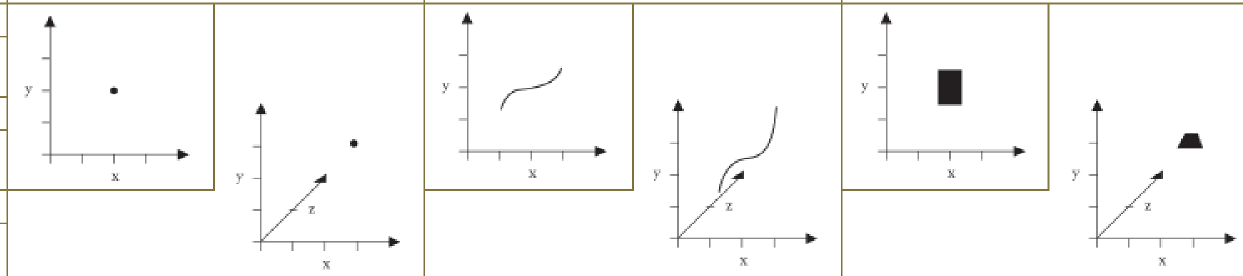
Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
• categorize/cluster	• nominal	• table	• geometric symbols	• spatial	• overview
• order/rank/sort	• ordinal	• chart	point	position	• zoom
• distributions	• interval	• graph	line	• retinal	• search and locate
(also outliers, gaps)	• ratio	• map	area	form	• filter
• comparisons		• network layout	surface	color	• details-on-demand
• trends			volume	optics	• history
(process and time)			• linguistic symbols	motion	• extract
• geospatial			text		• link and brush
• compositions			numerals		• projection
(also of text)			punctuation marks		• distortion
• correlations/relationships			• pictorial symbols		
			images		
			icons		
			statistical glyphs		

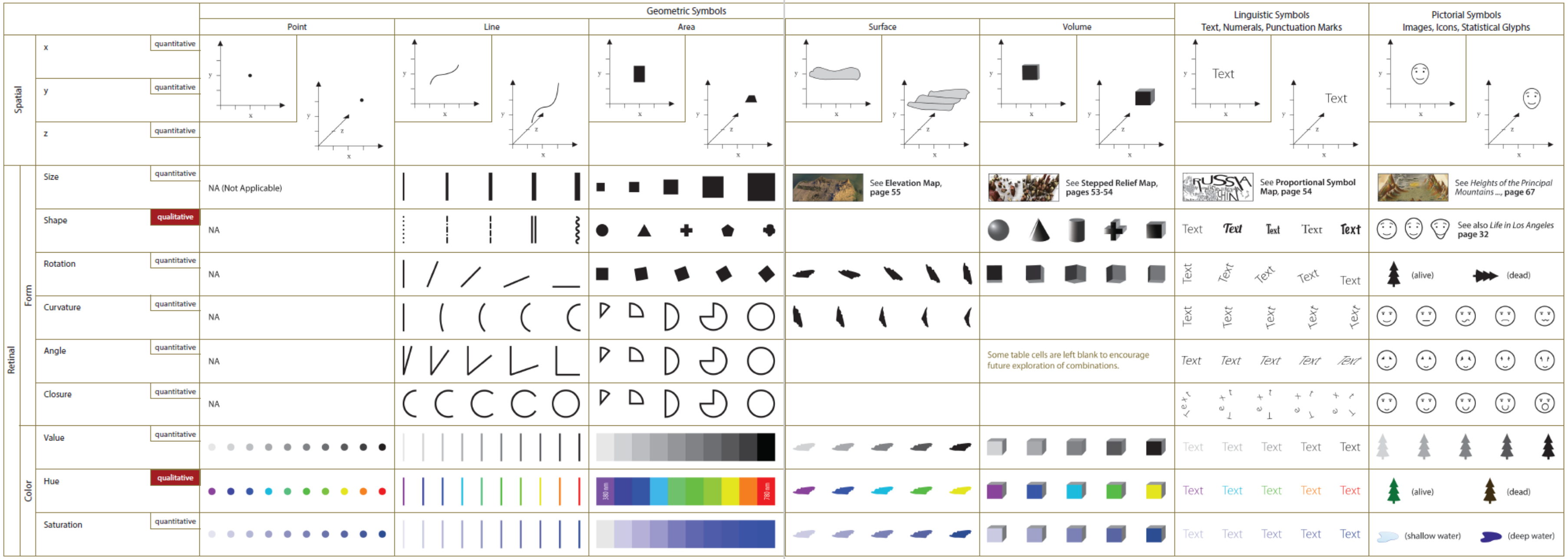


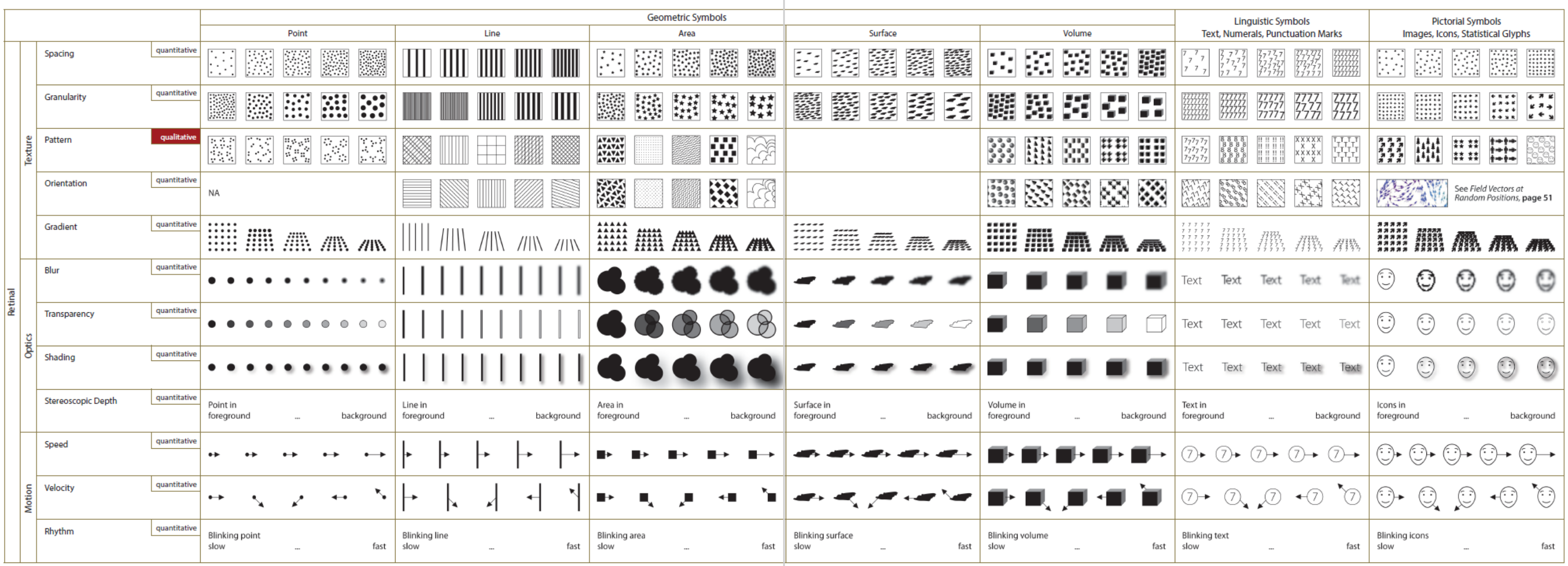
See *Atlas of Science: Anyone Can Map*, page 24

Graphic Variable Types Versus Graphic Symbol Types

				Geometric Symbols		
				Point	Line	Area
Spatial		x	quantitative			
		y	quantitative			
		z	quantitative			
Retinal	Form	Size	quantitative	NA (Not Applicable)		
		Shape	qualitative	NA		
		Rotation	quantitative	NA		
		Curvature	quantitative	NA		
		Angle	quantitative	NA		
		Closure	quantitative	NA		
	Color	Value	quantitative			
		Hue	qualitative			380 nm … 780 nm
		Saturation	quantitative			

Graphic Variable Types Versus Graphic Symbol Types





Course Schedule

Part 1: Theory and Hands-On

- **Session 1** – Workflow Design and Visualization Framework
- **Session 2** – “When:” Temporal Data
- **Session 3** – “Where:” Geospatial Data
- **Session 4** – “What:” Topical Data

Mid-Term

- **Session 5** – “With Whom:” Trees
- **Session 6** – “With Whom:” Networks
- **Session 7** – Dynamic Visualizations and Deployment

Final Exam

Part 2: Students work in teams on client projects.

Final grade is based on Homework and Quizzes (**10%),** Midterm (**20%**), Final (**30%**), Client Project (**30%**), and Class Participation (**10%**).

The IVMOOC Companion Textbook

This textbook offers a gentle introduction to the design of insightful visualizations. It seamlessly blends theory and practice, giving readers both the theoretical foundation and the practical skills necessary to render data into insights.

The book accompanies the Information Visualization MOOC that attracted students, scholars, and practitioners from many fields of science and more than 100 different countries.

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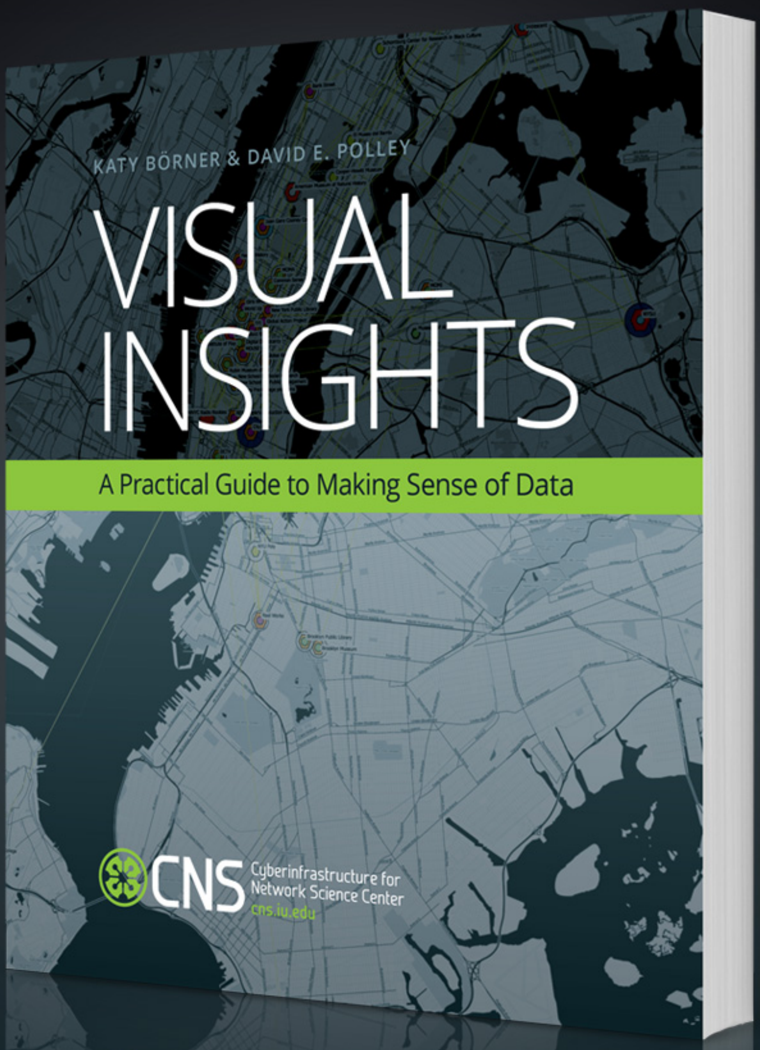
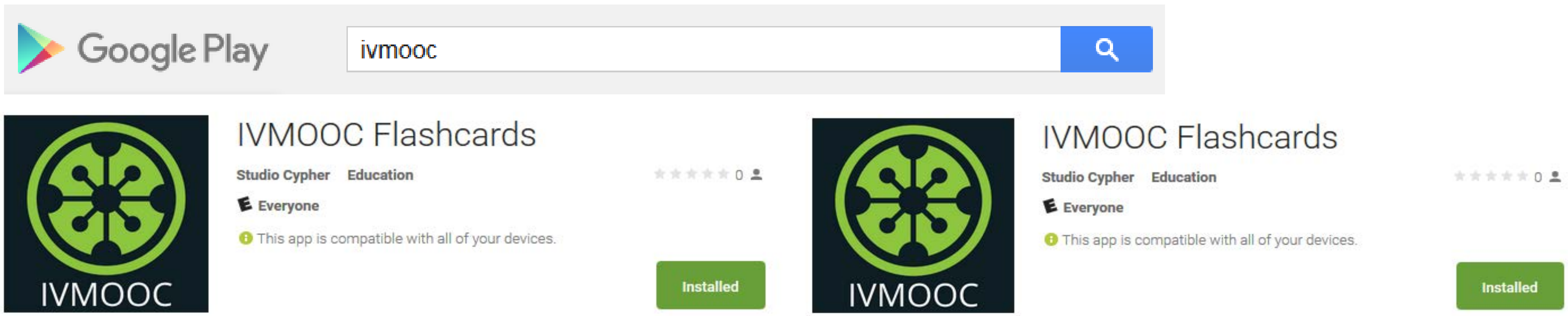
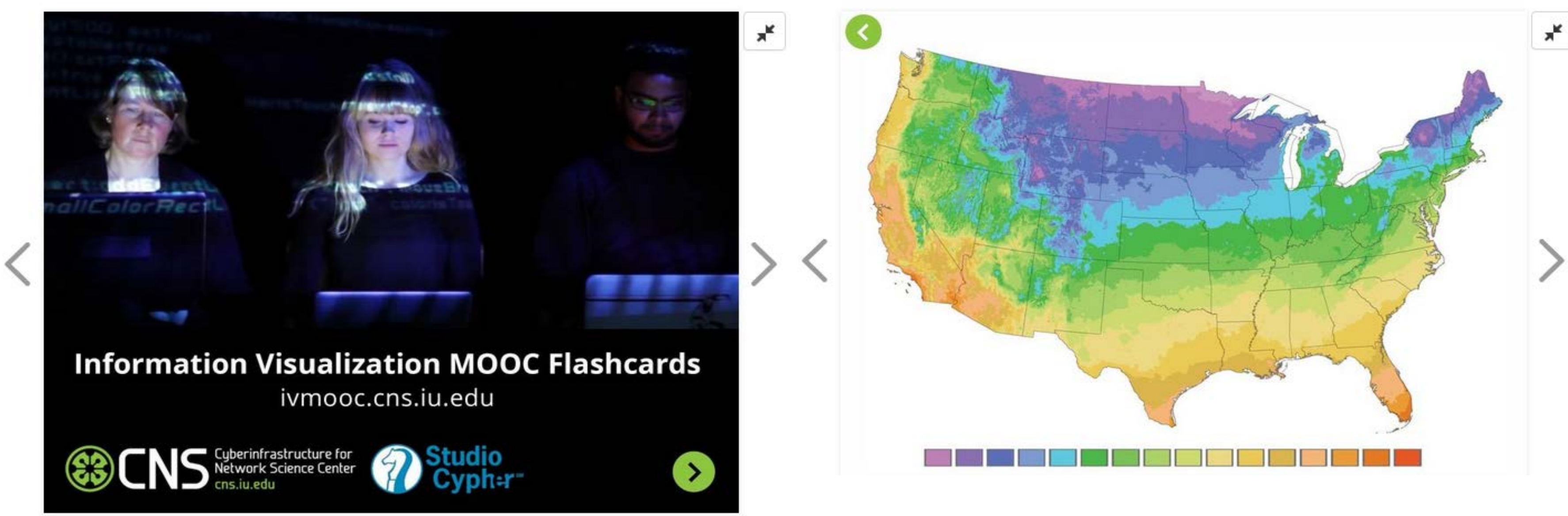


cns.iu.edu/ivmoocbook14.html

IVMOOC App

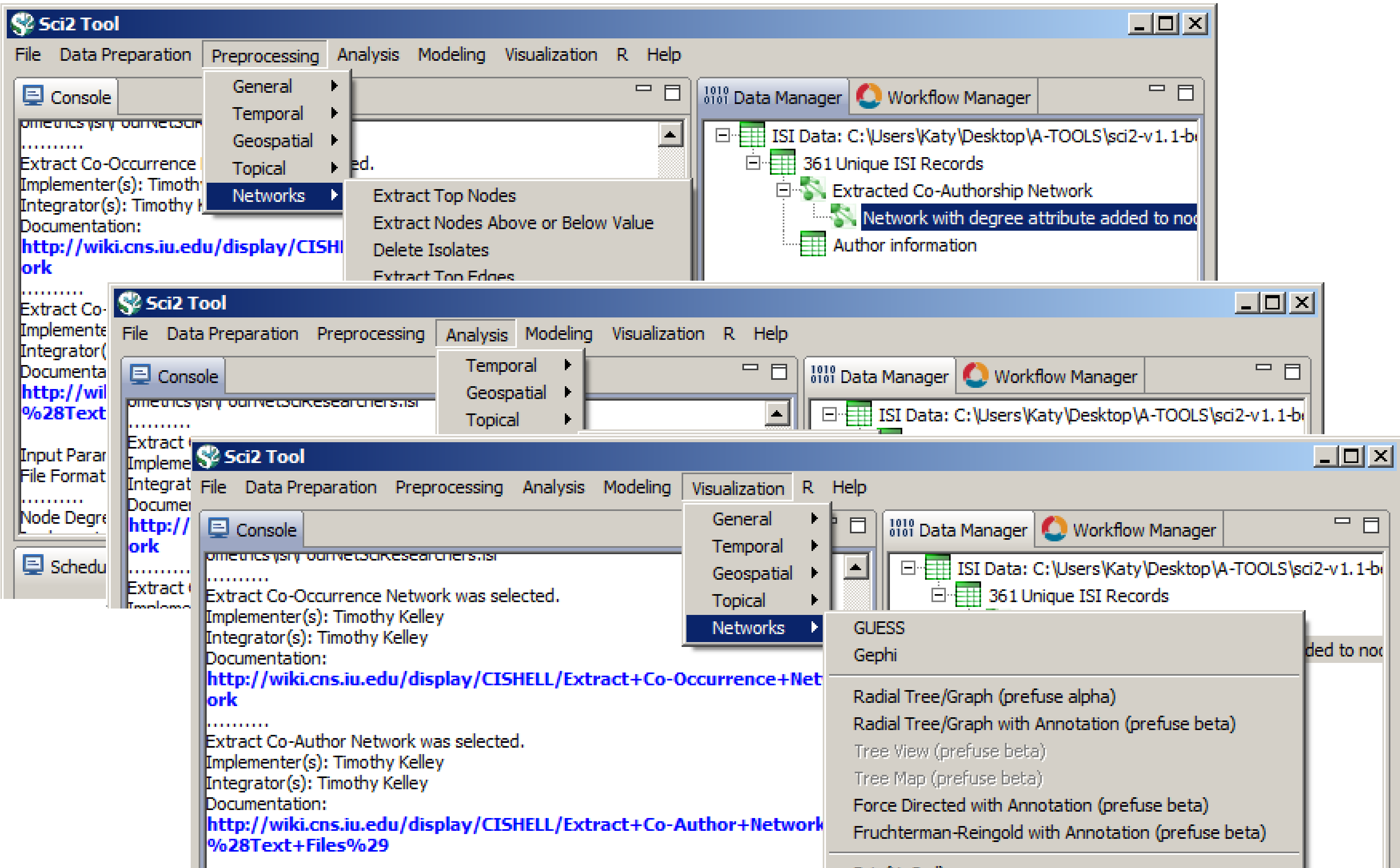
The “IVMOOC Flashcards” app can be downloaded from Google Play and Apple iOS stores.





Sci2 Tool Interface Components Implement Vis Framework

Download tool for free at http://sci2.cns.iu.edu



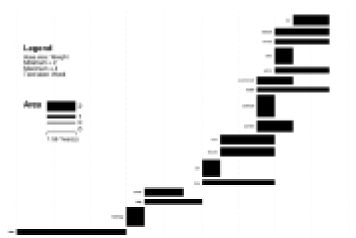
Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Macroscopes	Computer Science	Borner, K
18	2010	MALDEN	USA	CTS-CLINICAL AND TRANSLATIONAL SCIENCE	Advancing the Science of Team Science	Research & Experimental Medicine	Falk-Krzesinski, HJ|Borner, K|Contractor, N|Fiore, SM|Hall, KL|Keyton, J|Spring, B|Stokols, D|Trochim, W|Uzzi, B
13	2010	WASHINGTON	USA	SCIENCE TRANSLATIONAL MEDICINE	A Multi-Level Systems Perspective for the Science of Team Science	Cell Biology |Research & Experimental Medicine	Borner, K|Contractor, N|Falk-Krzesinski, HJ|Fiore, SM|Hall, KL|Keyton, J|Spring, B|Stokols, D|Trochim, W|Uzzi, B

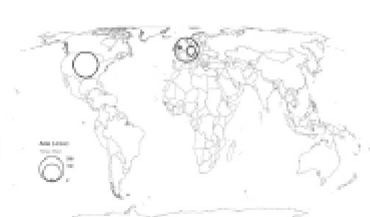
Statistical Analysis—p. 44

Location	*Count*	*# Citations*
Netherlands	13	292
United States	9	318
Germany	11	36
United Kingdom	1	2

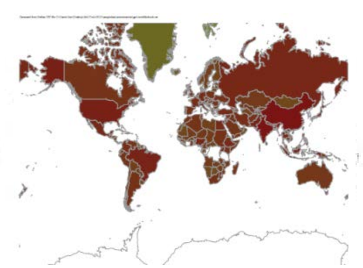
Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52



Geospatial Analysis—p. 52



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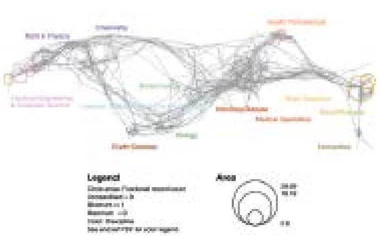
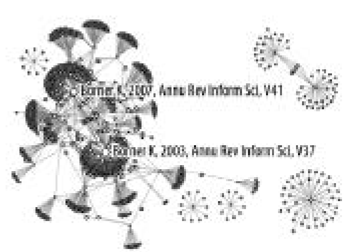
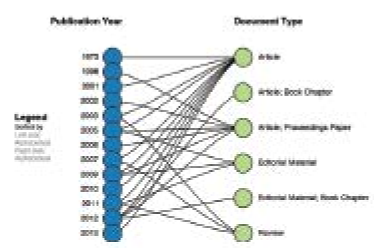
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60



Co-author and many other bi-modal networks.

Learning Analytics

Learning Analytics

Empowering Teachers: How to make sense of the activities of thousands of students? How to guide them?

Empowering Students: How to navigate learning materials and develop successful learning collaborations across disciplines and time zones?

Empowering Researchers: How do people learn? What pedagogy works (in a MOOC) and when?

Empowering MOOC Platform Designers: What technology helps and what hurts?

Visualizing IVMOOC Data

Data was collected from different sources:

- 1,901 students registered via GCB (1215 male/557 female)
- 52,557 slide downloads from our server
- 18,893 video views via YouTube
- 193 accounts made 730 tweets
- 134 students took 183 exams in GCB
- 674 remarks on 215 different forum threads in Drupal
- 64 students submitted projects via Drupal

Learning Analytics

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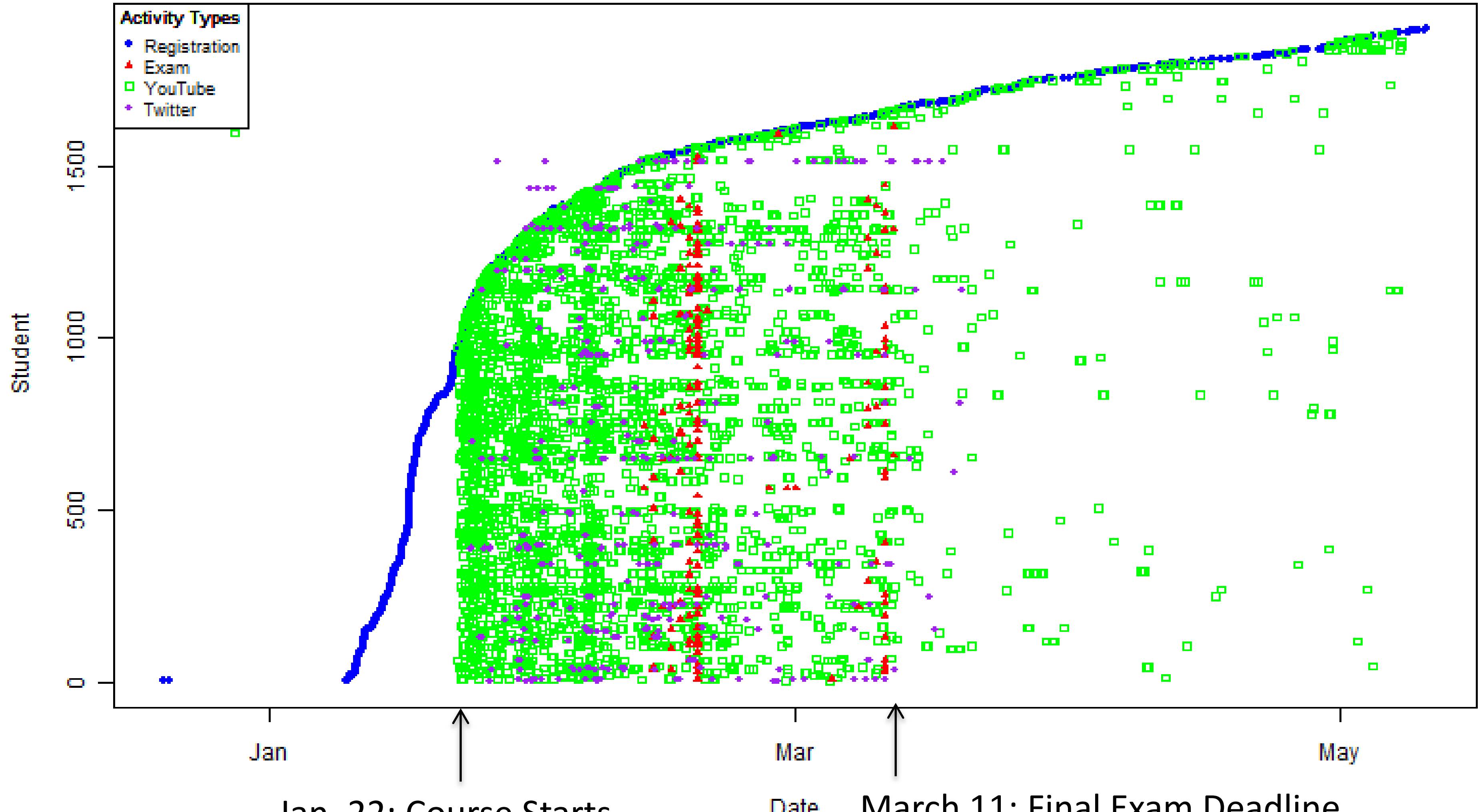
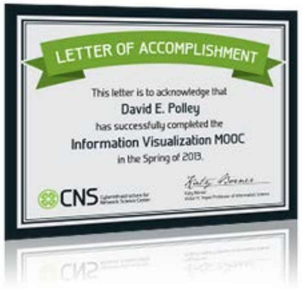
Student Registration and Activity



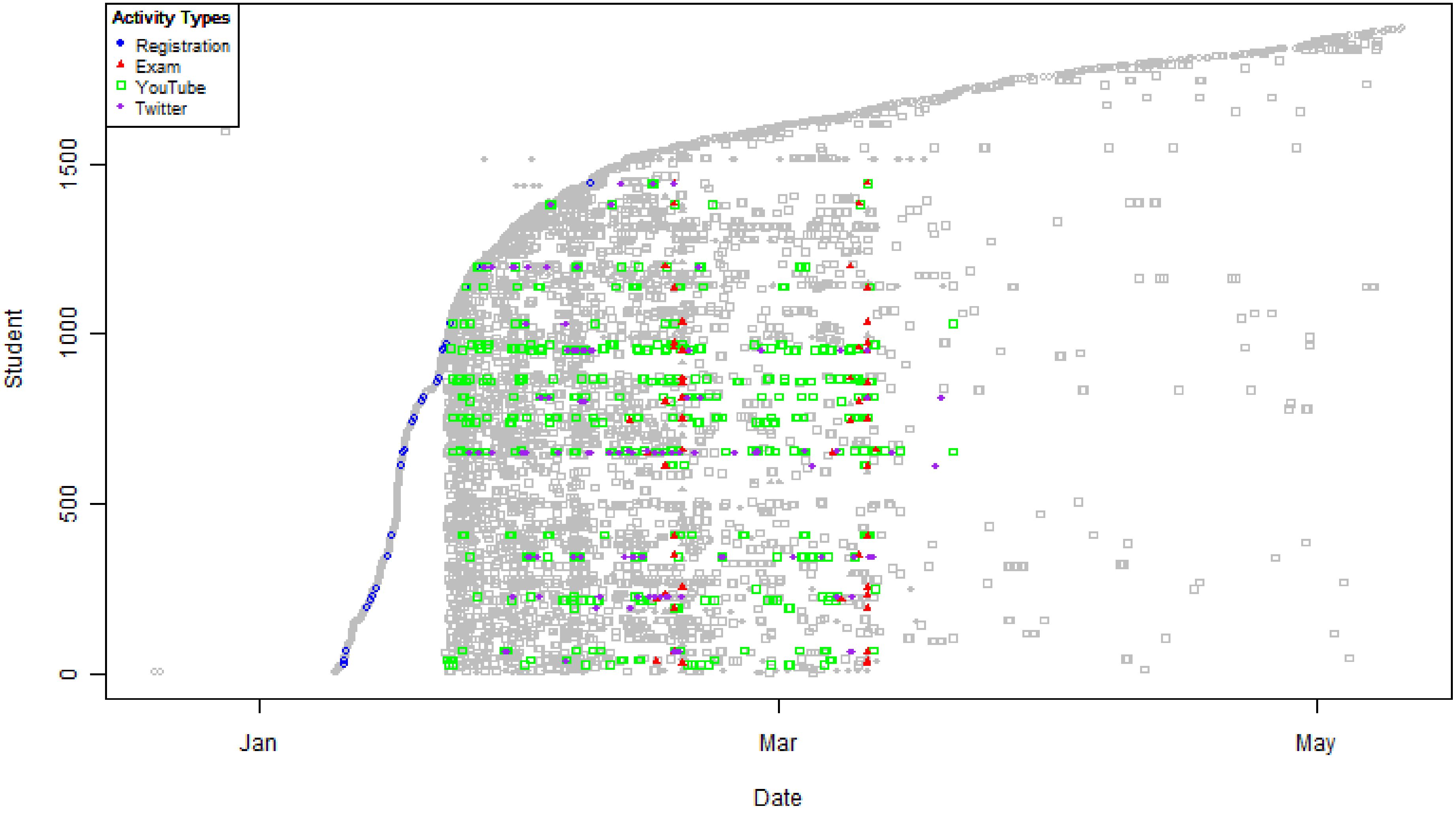
Jan. 22: Course Starts

March 11: Final Exam Deadline

Student Registration and Activity

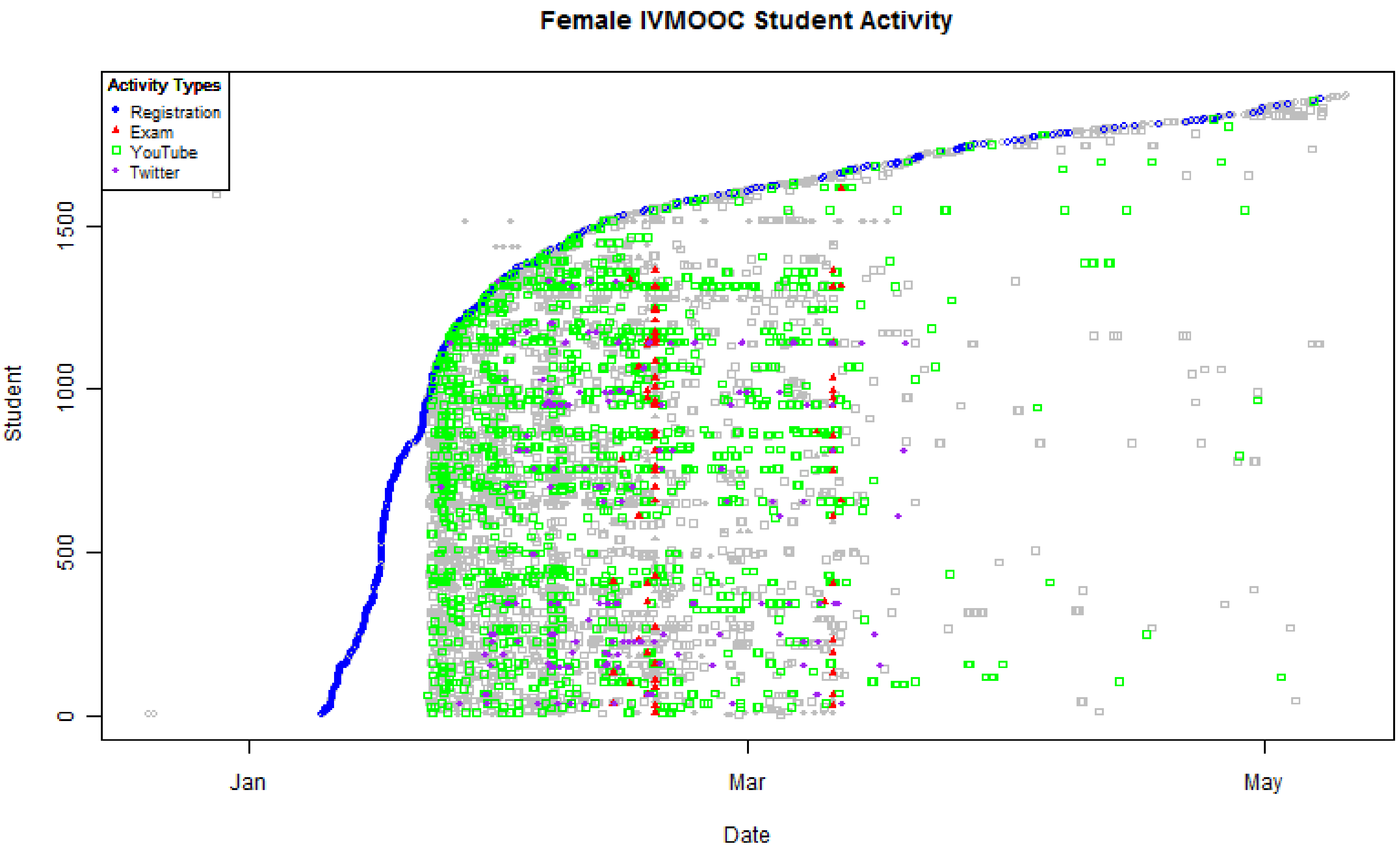


IVMOOC Student Activity (Achievement Badge)



Student Registration and Activity

1215 male students
557 female students



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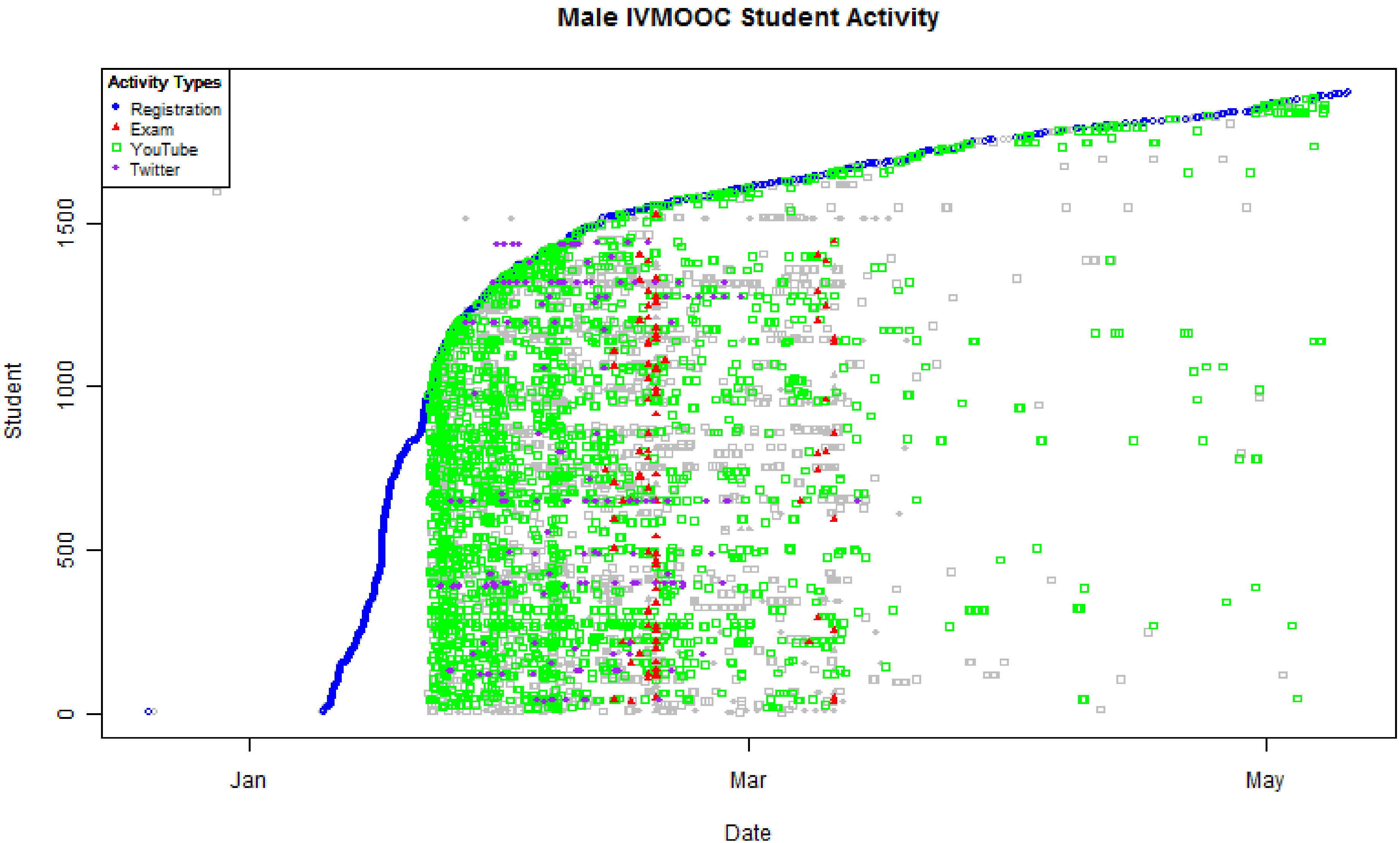
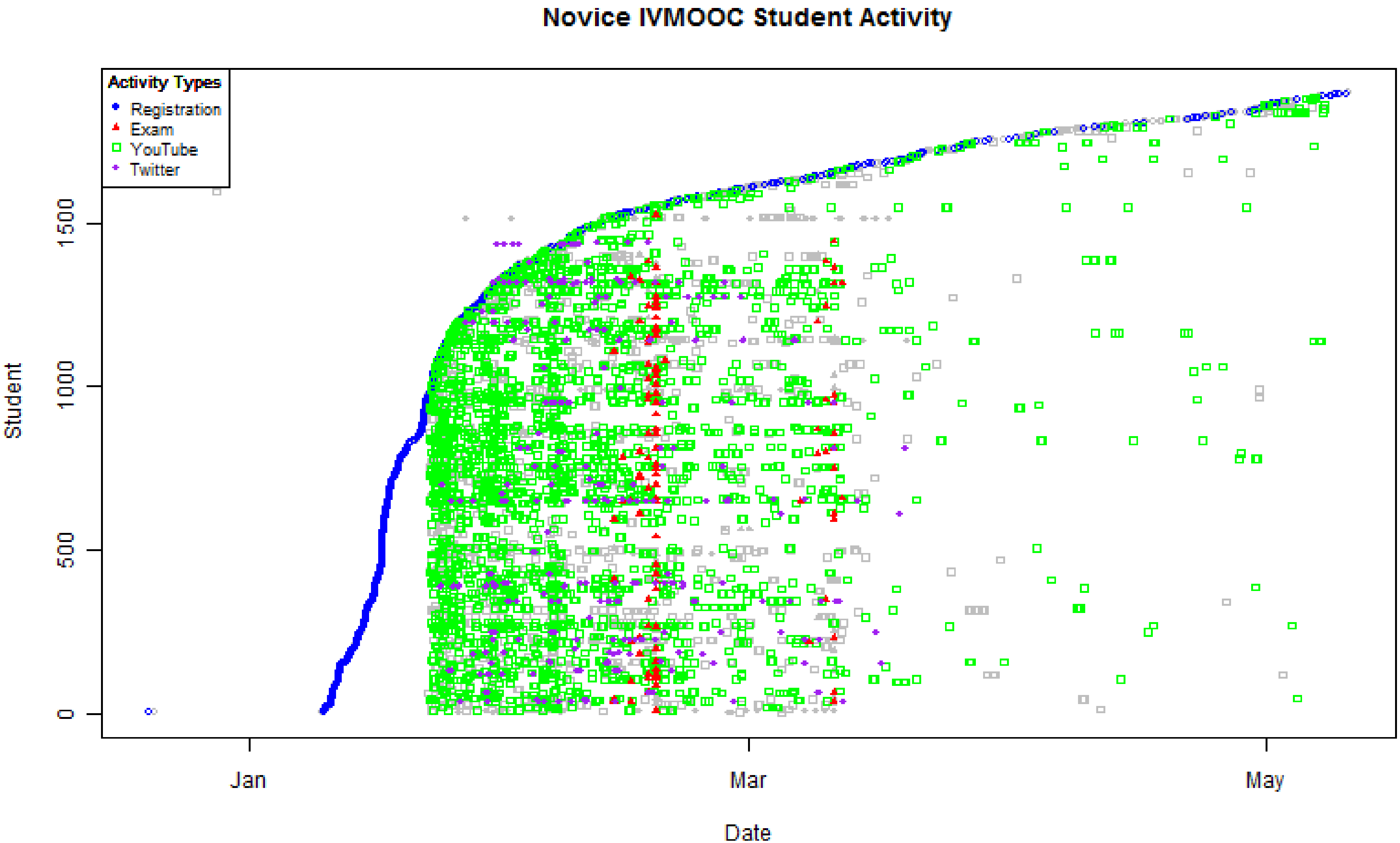
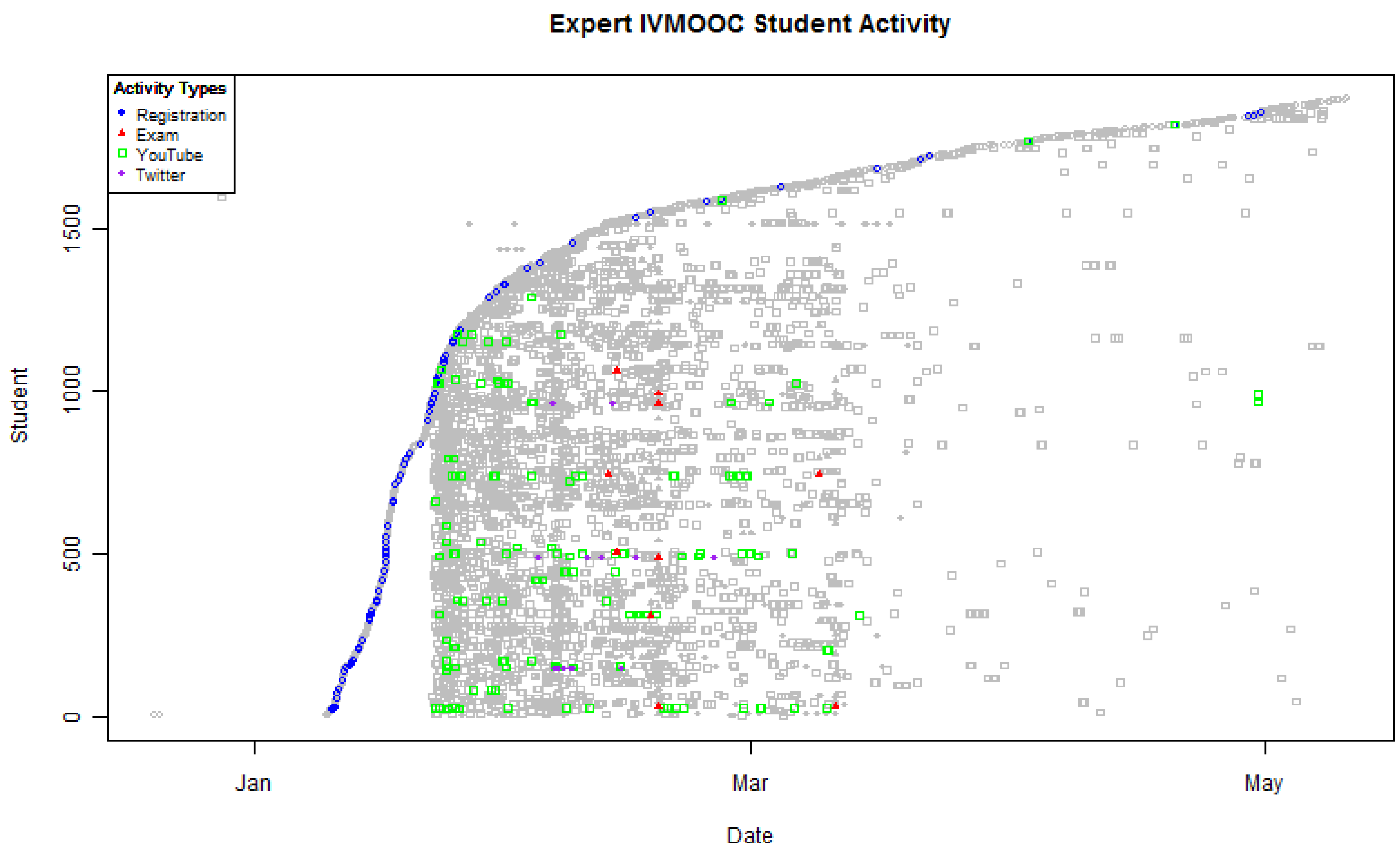


Student Registration and Activity



Student Registration and Activity



IVMOOC

Student Client Projects: All Interactions

Student Engagement and Performance

Learning Analytics

IVMOOC 2015 Student Group Engagement and Scores

	Pre-Course	Week 1	Week 2	Week 3	Week 4	Midterm	Week 5	Week 6	Week 7	Week 8	Week 9	Final	Curr. Score
IVMOOC	26.05%	38.32%	31.32%	29.96%	27.1%	28.34%	31.07%	24.28%	16.86%	18.23%	13.08%	13.41%	20.87%
Z637-29374	33.01%	52.91%	49.89%	59.22%	50.89%	82.56%	65.04%	49.99%	39.59%	61.63%	54.91%	82.25%	82.4%
Z637-32593	25.08%	54.54%	43.58%	50.67%	53.63%	77.67%	65.7%	59.48%	52.19%	65.71%	47.27%	72.59%	75.13%
Z637-33781	29.33%	55.38%	49.26%	62.18%	77.47%	85%	87.4%	69.8%	55.56%	57.6%	45.69%	70.89%	77.94%

IVMOOC 2015 Student Group Engagement for Midterm

	Midterm	Final	Curr. Score	Overall Engagemer
Student 198	100%	85.33%	92.67%	30.34%
Student 210	100%	84%	92%	33.91%
Student 242	97.14%	98.67%	97.9%	55.89%
Student 265	95.71%	92%	93.86%	82.64%
Student 216	95.71%	24%	59.86%	34.92%
Student 257	94.29%	98.67%	96.48%	68.25%
Student 264	94.29%	89.33%	91.81%	80.47%
Student 262	94.29%	85.33%	89.81%	79.65%

Legends

Engagement

Inactive Active Very Active

0% 25% 50% 75% 100%

Score

F D C B A

0% 60% 70% 80% 100%

Description

The heat map visualization is a representation of student engagement (magenta to blue color scale) and performance (red to green color scale) throughout a course. The visualization has two levels. The top level provides an overview of engagement and performance for groups of students, while the bottom level provides a detailed break out of student engagement statistics for individuals with an identified group.

Custom interactive visualizations of IVMOOC student engagement and performance data, explore functionality online at http://goo.gl/TYixCn

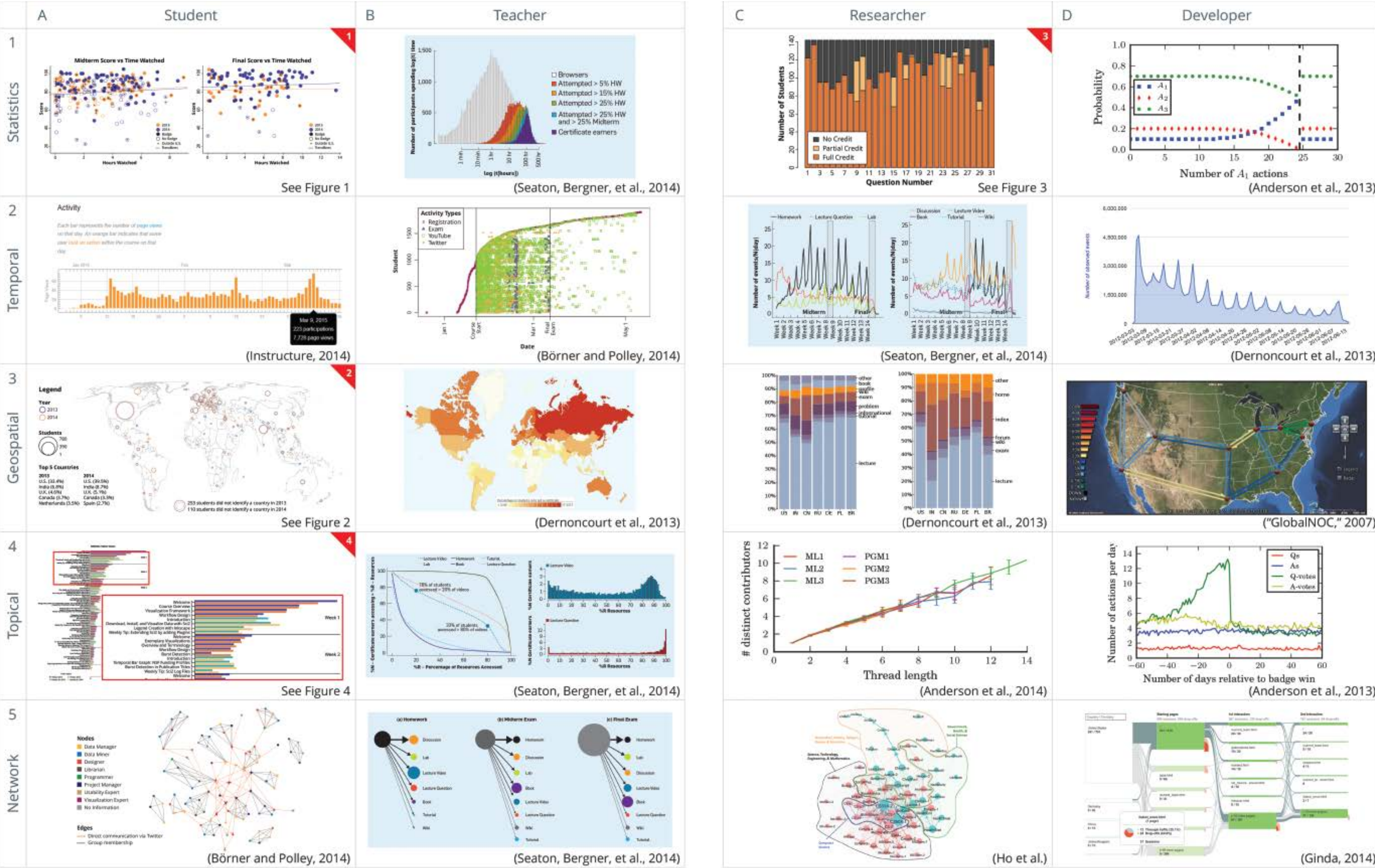


Figure 1: Analysis types vs. user needs.

Emmons, Light, and Börner. ["MOOC Visual Analytics: Empowering Teachers, Students, Researchers, and Developers of Massively Open Online Courses"](). *Journal of the Association for Information Science and Technology (in press)*.

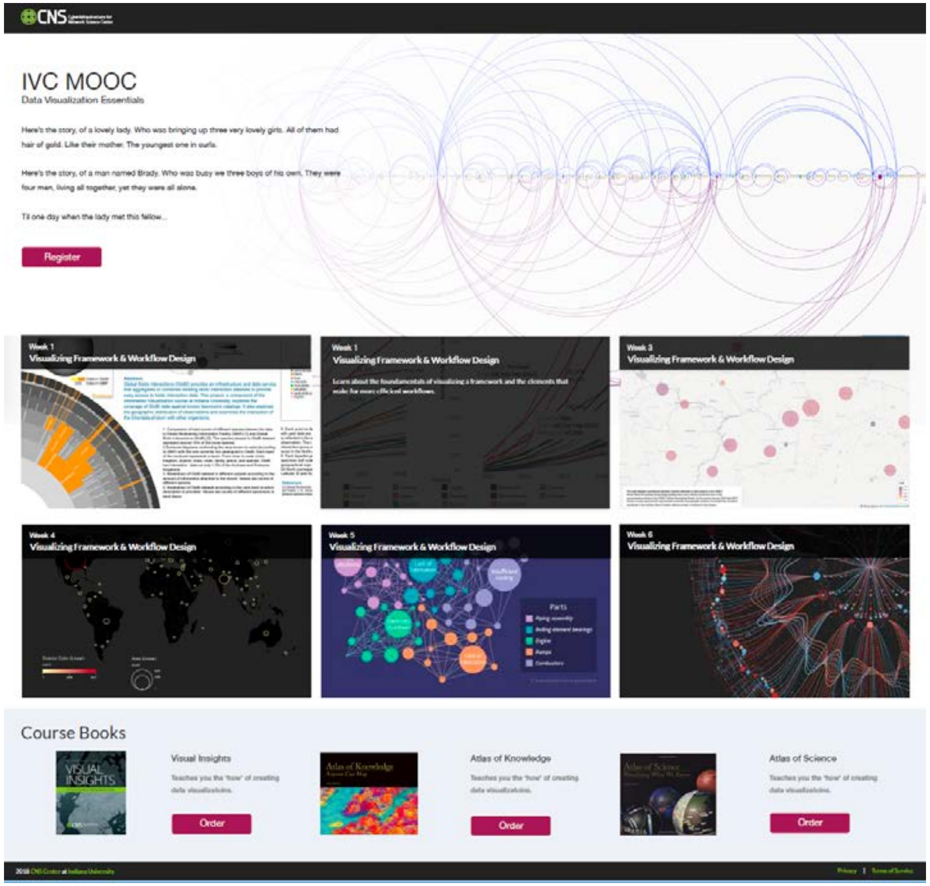
Next Generation IVMOOC

Instructor: Victor H. Yngve Distinguished Professor Katy Börner & CNS Team, ISE, SICE, IUB

Duration: *6 weeks x 5 hours = 30 hours (3 CEUs)*

Format: *Online | Theory and Hands-on Instruction, Concept Questions, Graded Assignments, Case Studies, Discussions*

Start: *Sept 15, 2018*



Covers:

Temporal, geospatial, topical (linguistic), network analyses and 60+ visualization types

Tools: Tableau, Gephi, BI,

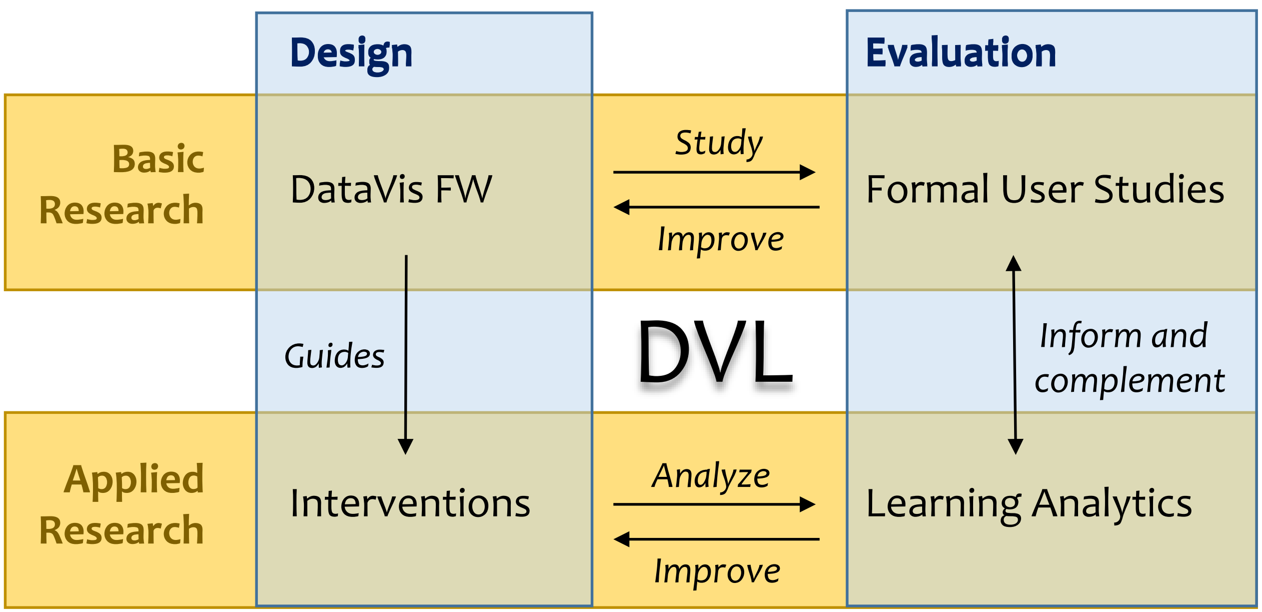
Industry case studies such as

- Acting on customer complaints data.
- Improving communication/traffic flows.
- Understanding web page usage.
- Visualizing online shopping behavior.
- Optimizing supply chains.
- Reducing customer/supplier churn.
- Monitoring emerging R&D areas.
- Workforce development planning.

Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using Mechanical Turk formal user studies and extensive learning analytics.

Optimization of **Data Visualization Framework** and **Learning Modules.**



Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using **Mechanical Turk formal user studies**, e.g., to optimize horizontal transfer:

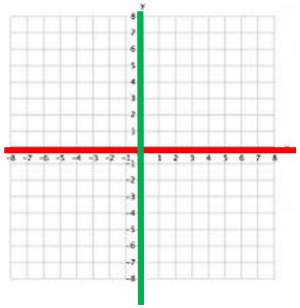
Table
Columns by rows

column row

x	y
0	3
2	11
4	19
6	27
8	35

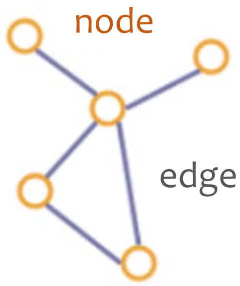
cell

Graph
x-y coordinates
linear/log scale



Map
Latitude/
longitude

Network
Local
similarity



Horizontal Transfer

Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using **Learning Analytics** to optimize scaffolding and learning trajectories:

Scaffolding

Insights
Trends, clusters, outliers

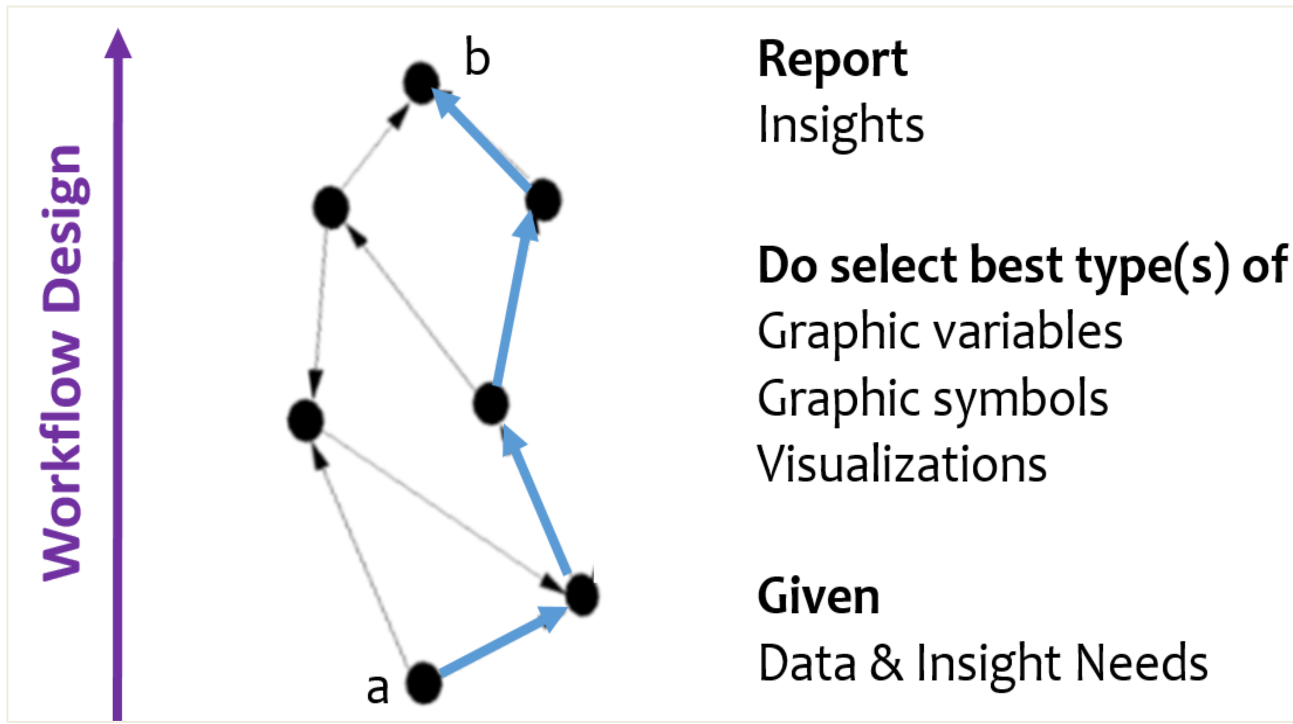
Interactivity
Zoom, filter, details-on-demand

Graphic variables
Position, color, size, shape code

Graphic symbols
Geometric, linguistic, or pictorial

Visualizations
Table, graph, map, network

Insight Needs & Data



MIT xPRO: Systems Engineering

MIT, Boeing, NASA, and edX to launch online architecture and systems engineering program

Four-course program will train professionals in latest practices on models and methods to manage complex systems

https://sysengonline.mit.edu

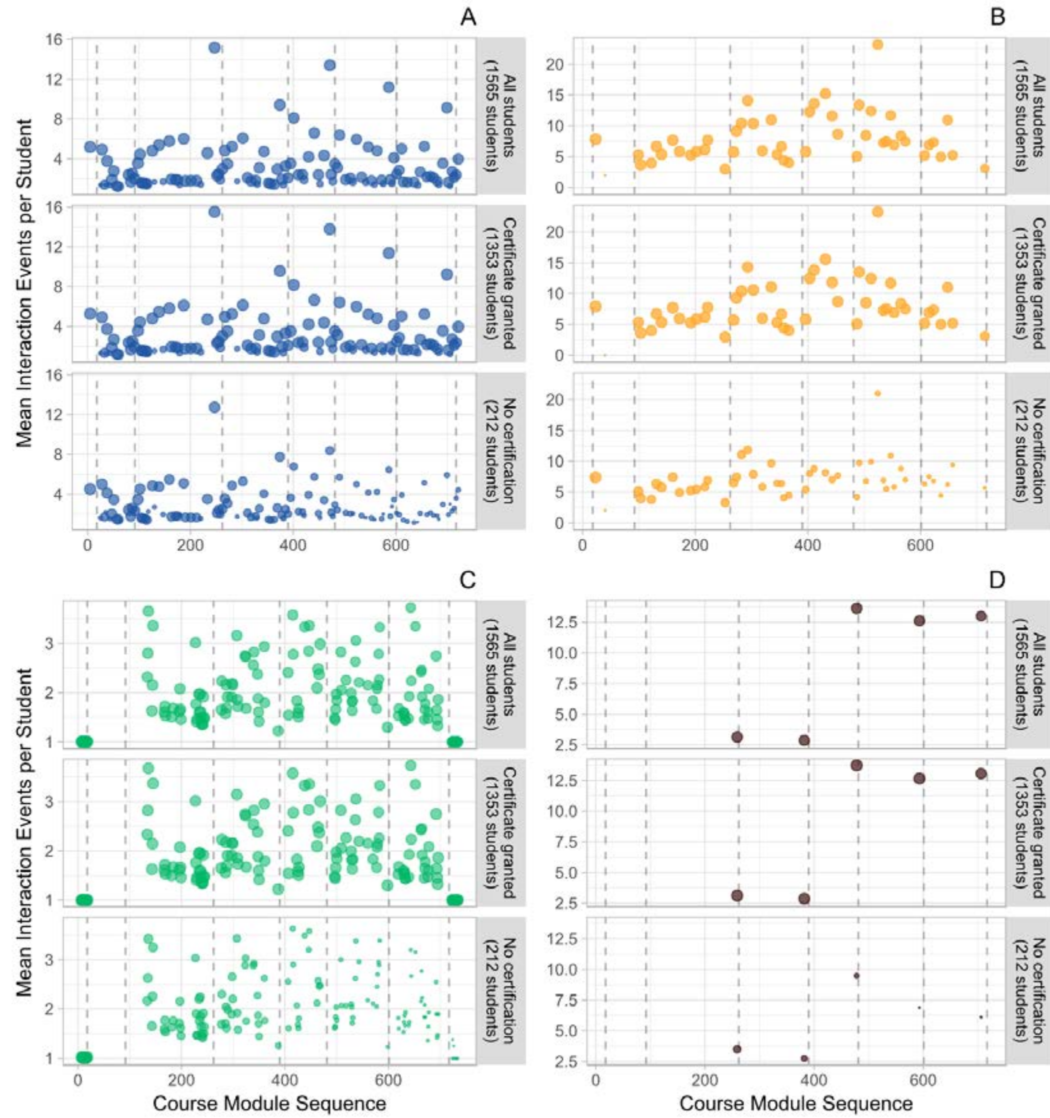
Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner

MIT xPRO Course "Architecture of Complex Systems" delivered via the edX platform in Fall 2016.

1,611 Boeing engineers registered; 1,565 were active and generated nearly **31 million click event records** while accessing videos, projects, and assessments. Some students generated over 100,000 separate events.

All but 255 engineers passed the course, resulting in a completion rate of 84.1%.



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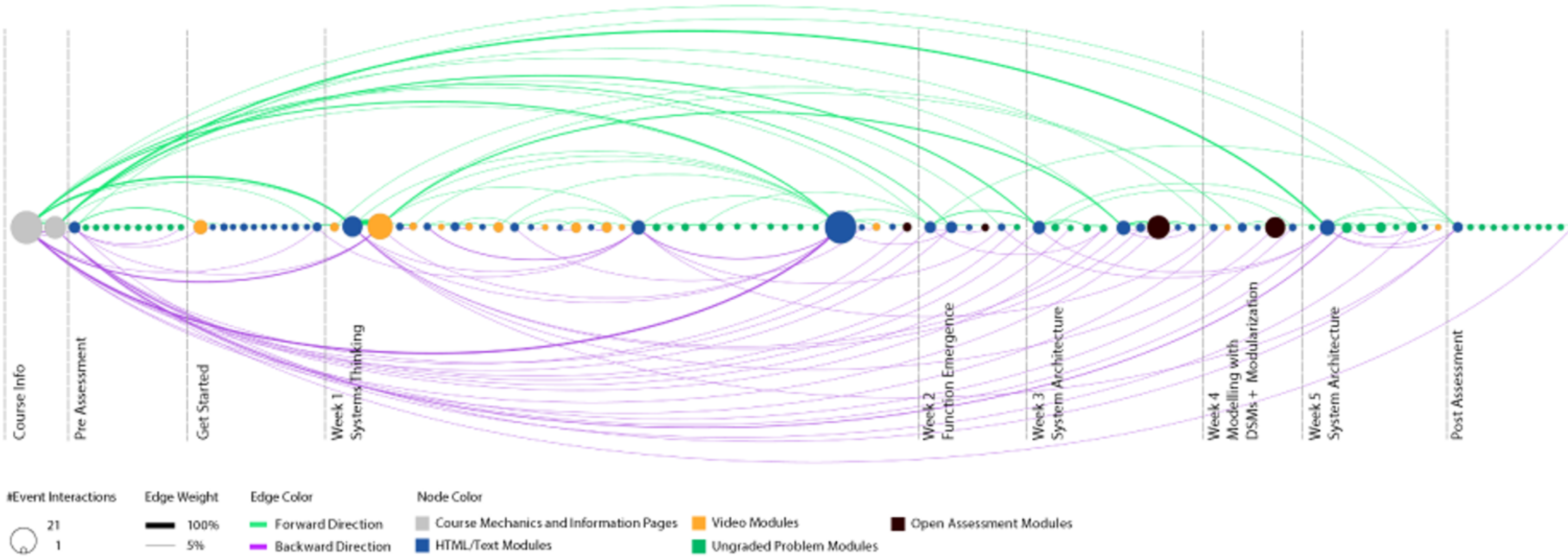

Figure 1: Learner path overlaid on linear sequence of course modules. Linear, temporal sequence of learning modules accessed by a high performing student plotted from left (first) to right (last) with dividing lines for pre and post but also week 1-5 modules.

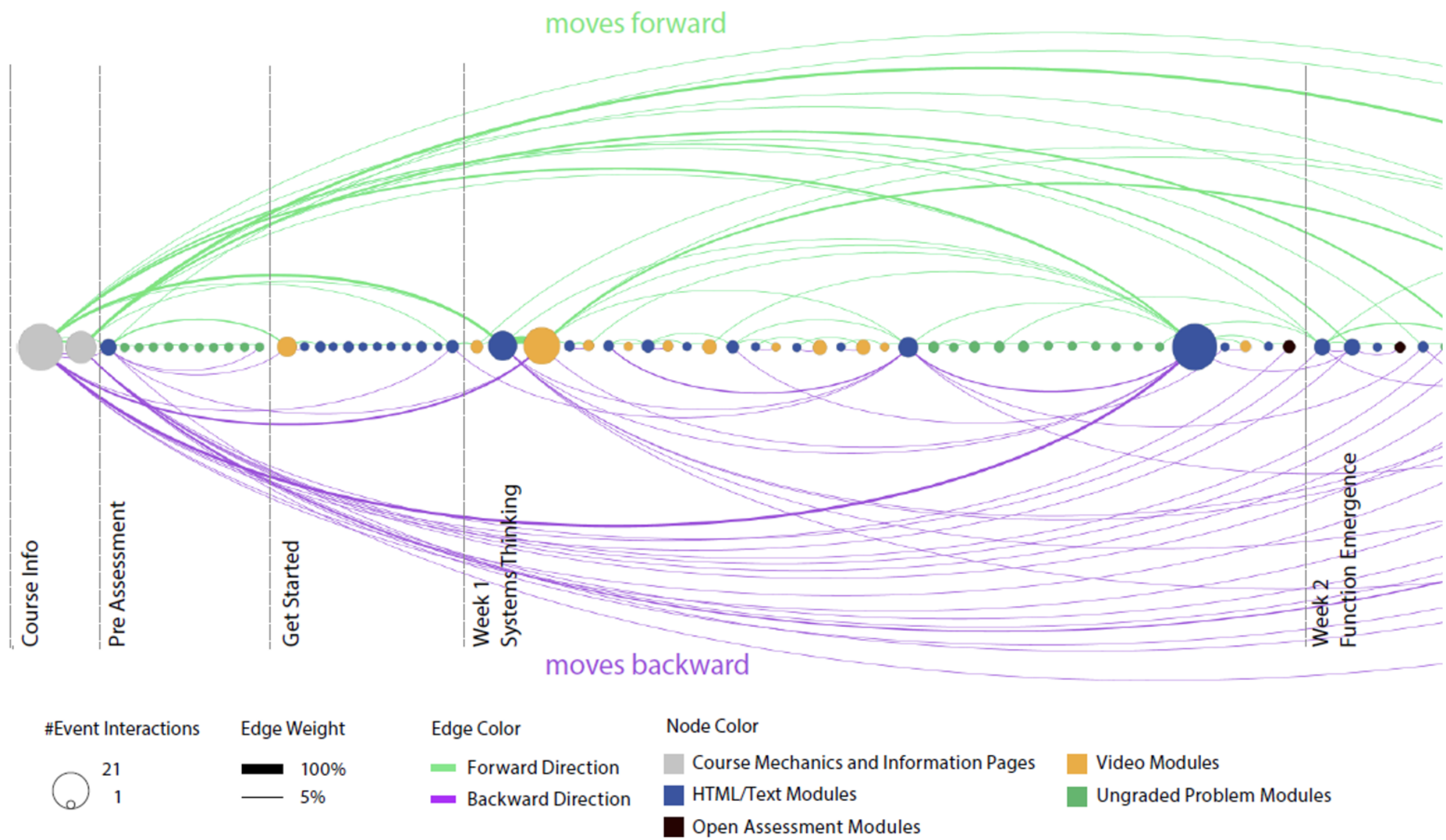

Figure 2. Zoom into learner path overlaid on linear sequence of course modules. Linear, temporal sequence of course modules used by a high performing student; plotted from left (first) to right (last) with dividing lines for different module sections.

Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

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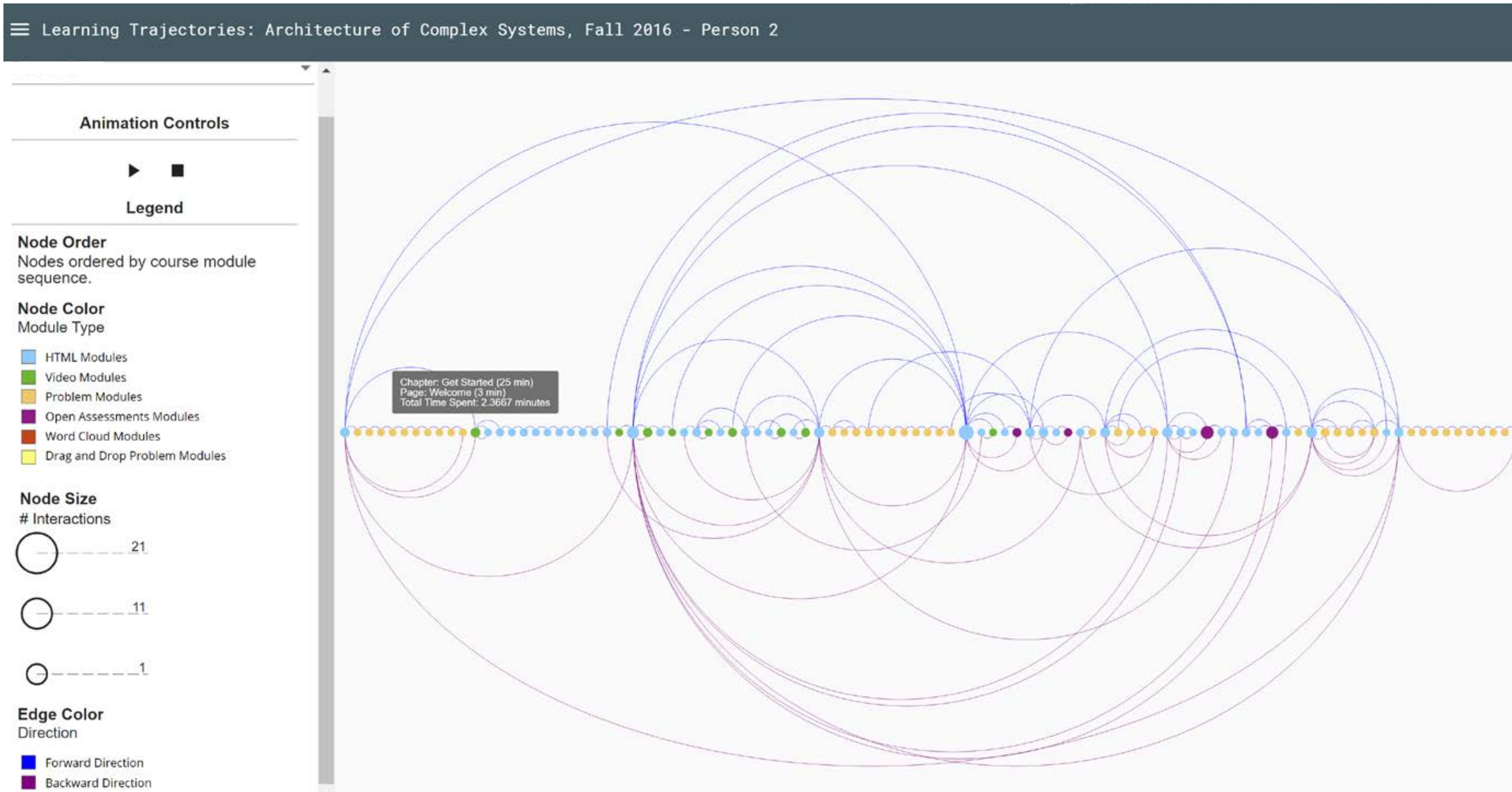


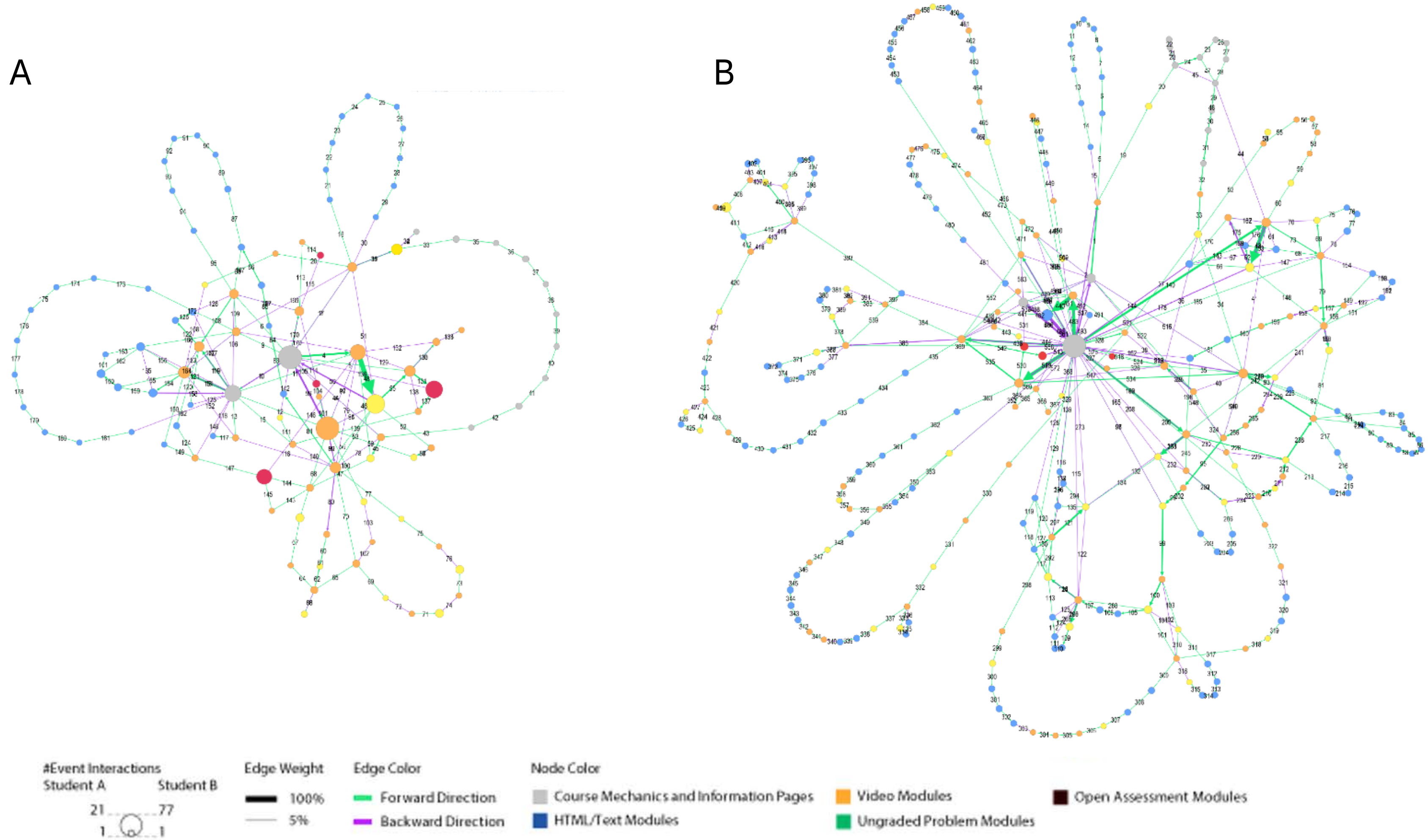


Figure 3: Learner path overlaid on force-directed layout of used course modules. Learner path of a students with high (left) and low (right) performance scores overlaid on force-directed layout of course modules.

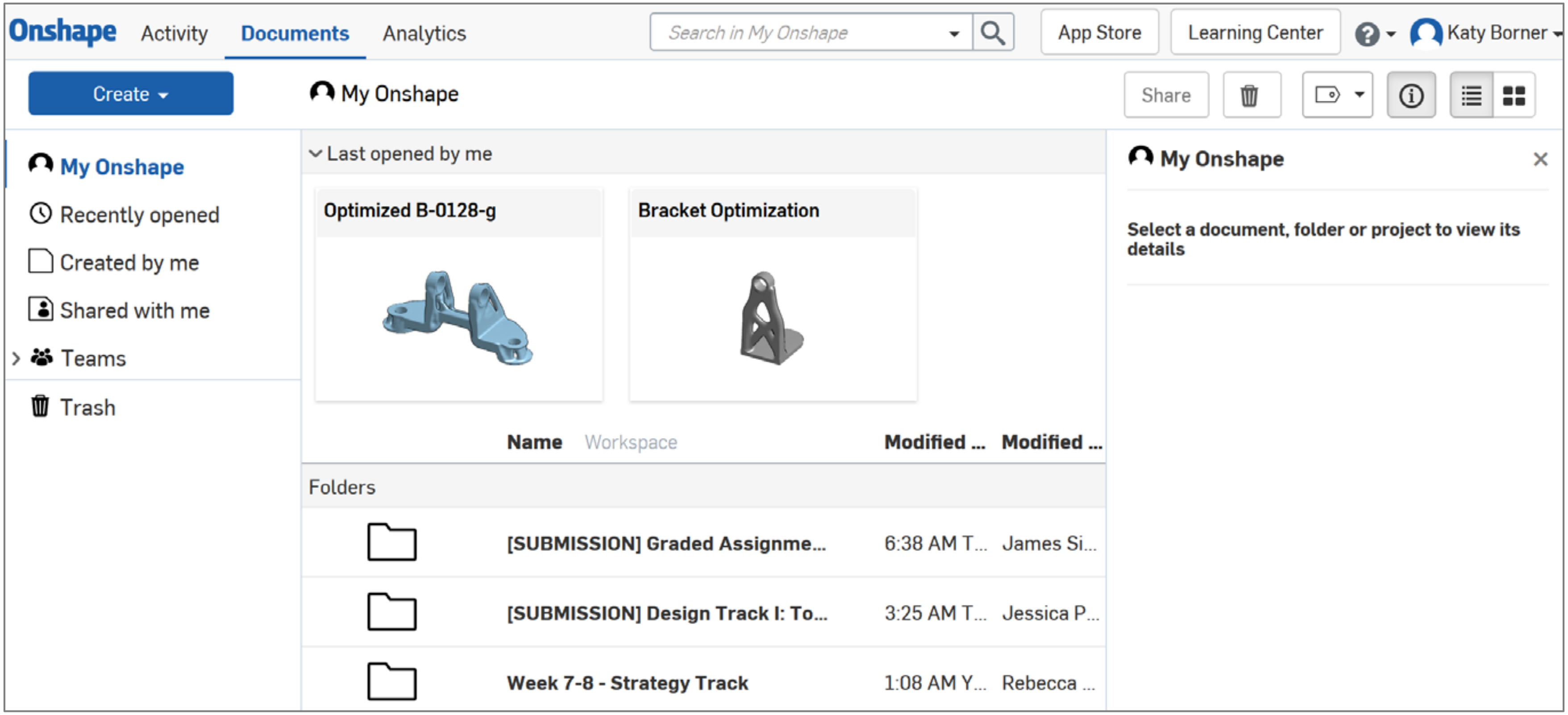
MIT xPRO: Additive Manufacturing

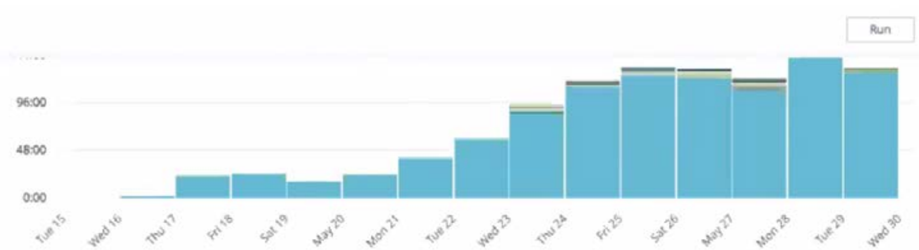
MIT xPRO

HOME ENTERPRISE

https://additivemanufacturing.mit.edu

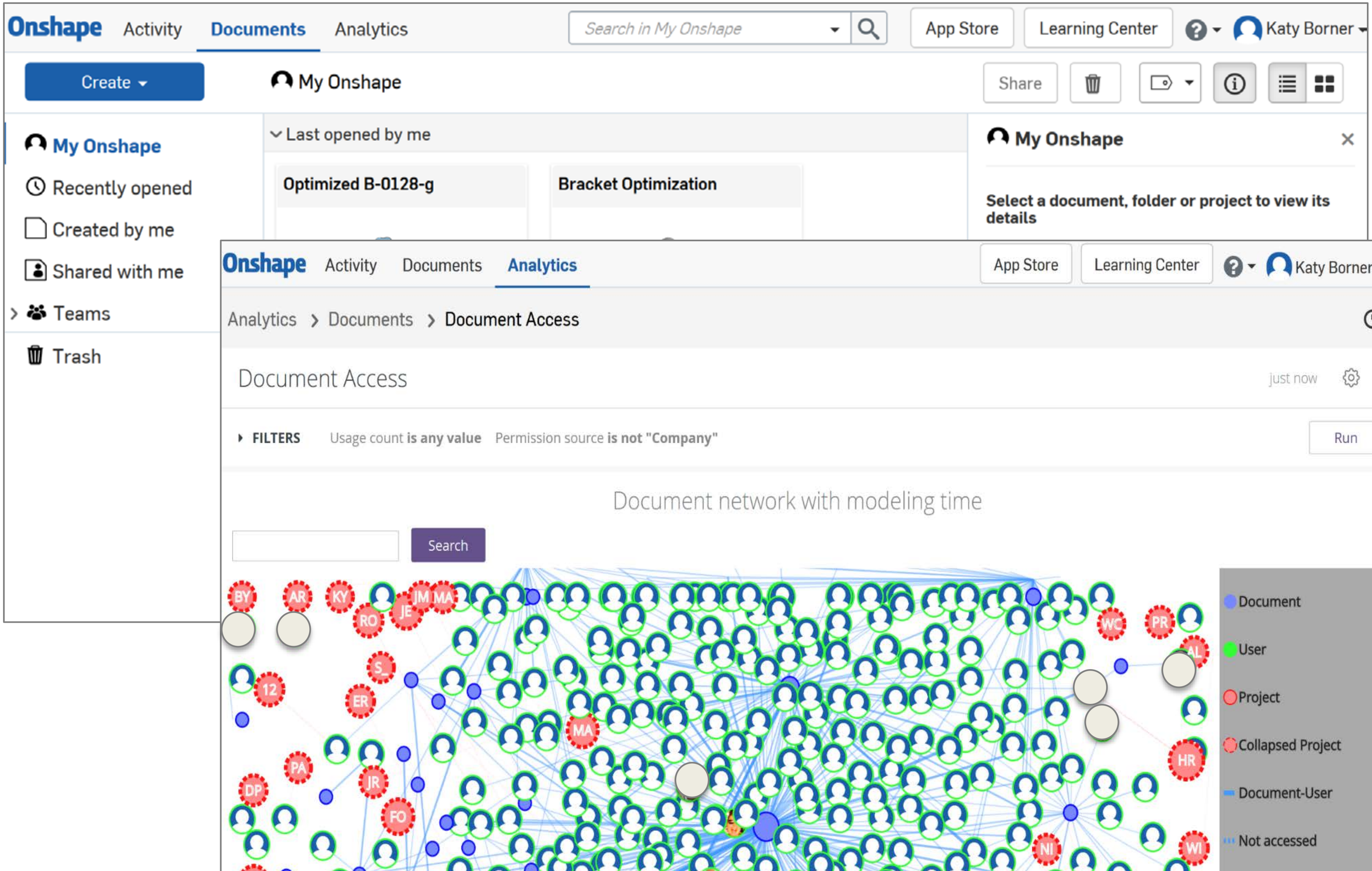
Students use Onshape to practice what they learned





Login Locations

Students use Onshape to practice what they learned



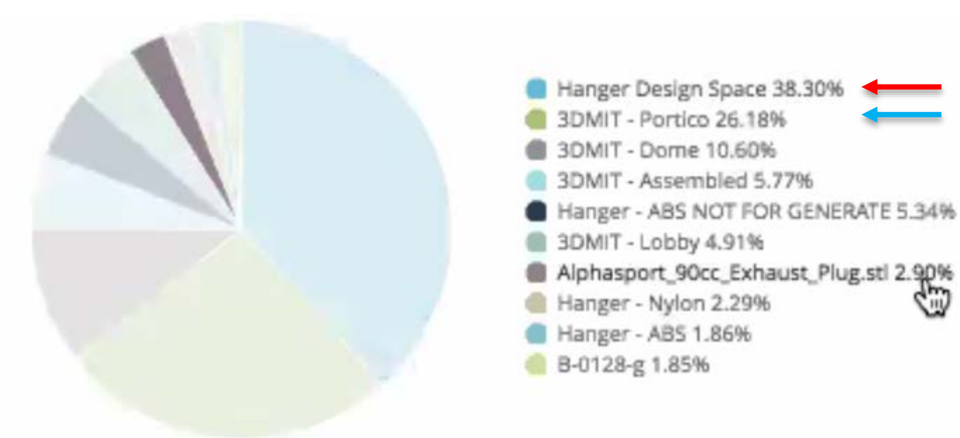
Additive Manufacturing

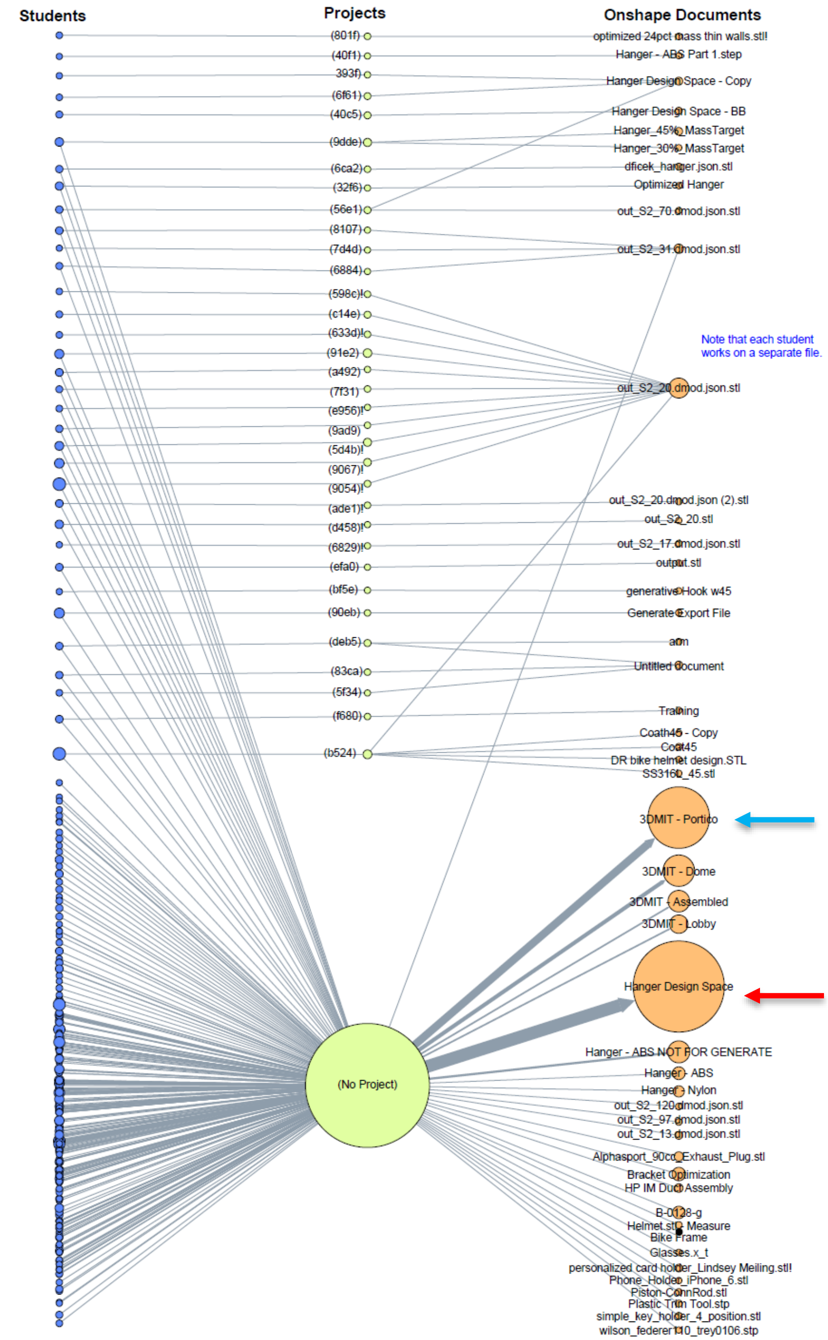
3-modal network of all Students (blue), Teams (green), Documents (orange) used in course by May 31, 2018.

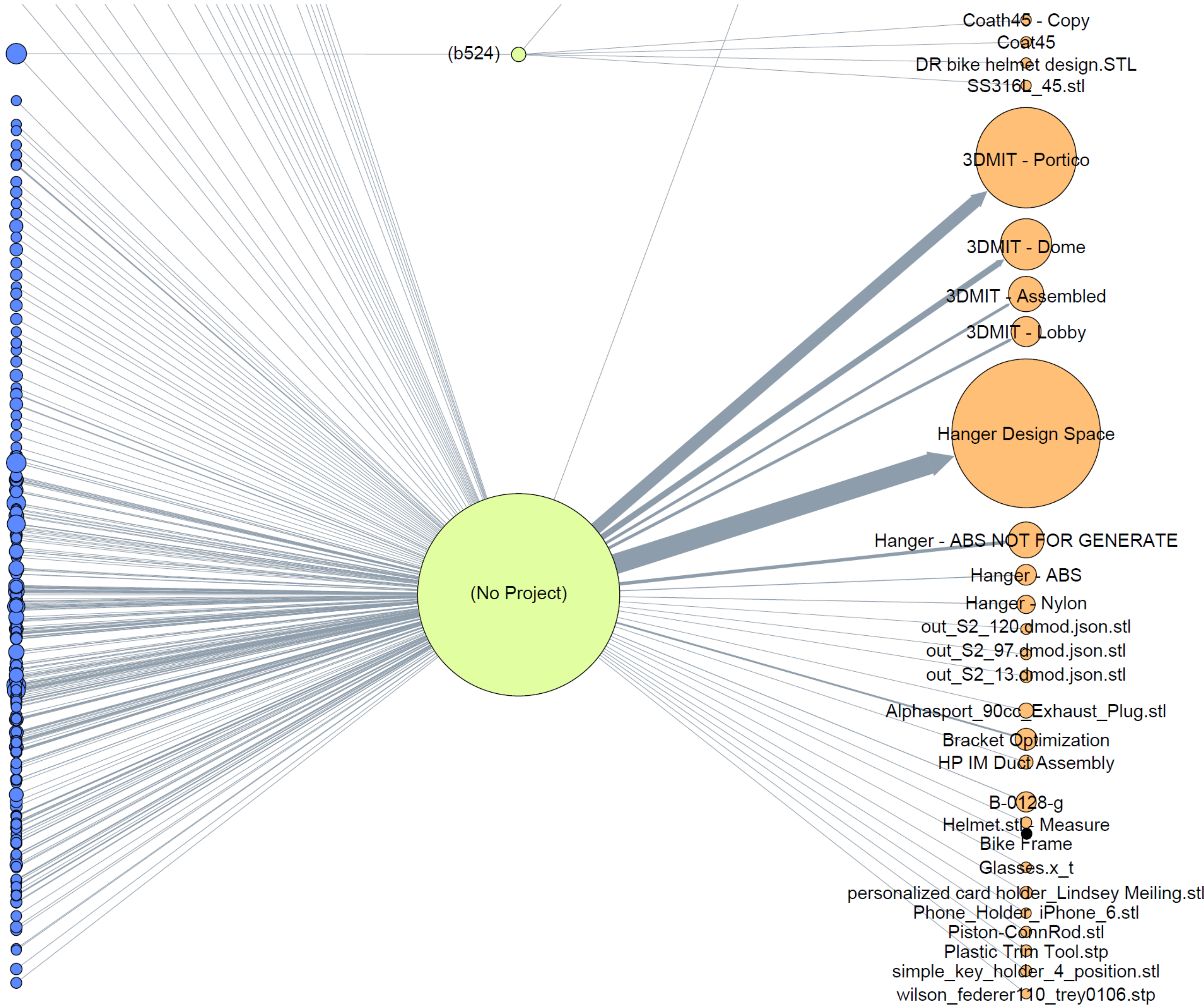
Area size represents the total time associated with a given node in the modeling software.

- Top Student - 16.91 hours
- *(b524)* Project - 7.74 hours
- *Hanger Design Space* Document - 367.28 hours

Edge thickness denotes number of times an relationship occurred in the data.






(b524)
Coath45 - Copy
Coat45
DR bike helmet design.STL
SS316L_45.stl
3DMIT - Portico
3DMIT - Dome
3DMIT - Assembled
3DMIT - Lobby
Hanger Design Space
(No Project)
Hanger - ABS NOT FOR GENERATE
Hanger - ABS
Hanger - Nylon
out_S2_120.dmod.json.stl
out_S2_97.dmod.json.stl
out_S2_13.dmod.json.stl
Alphasport_90cc_Exhaust_Plug.stl
Bracket Optimization
HP IM Duct Assembly
B-0128-g
Helmet.stl - Measure
Bike Frame
Glasses.x_t
personalized card holder_Lindsey Meiling.stl
Phone_Holder_iPhone_6.stl
Piston-ConnRod.stl
Plastic Trim Tool.stp
simple_key_holder_4_position.stl
wilson_federer110_trey0106.stp

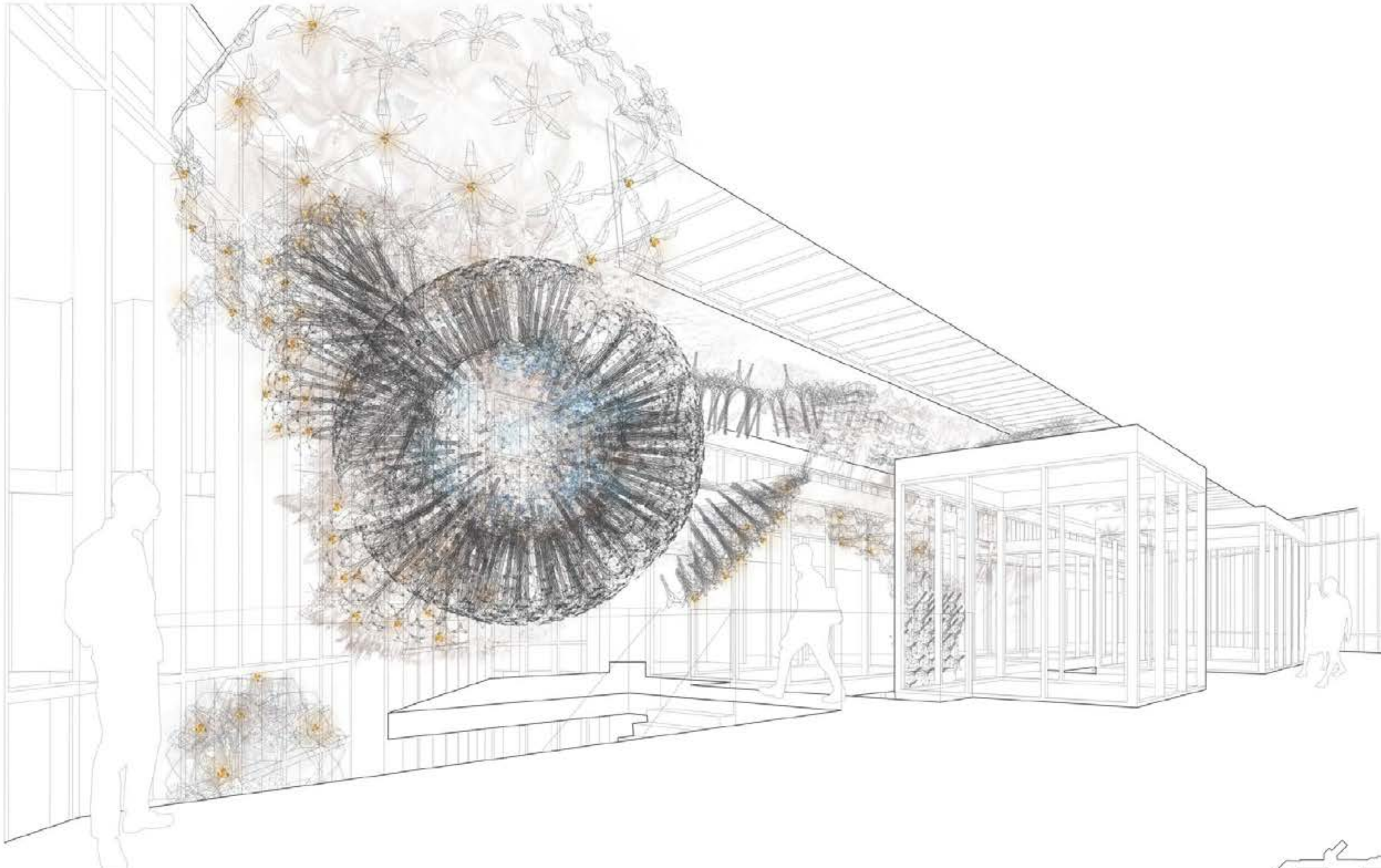
Embracing Human and Machine Intelligence Symbiosis

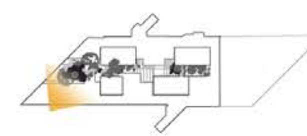
Visualizing the Internet of Things (IoT)

Using large scale datasets, advanced data mining and visualization techniques, and substantial computing resources.

Work by Philip Beesley | www.philipbeesley.ca | www.lasg.ca

Sentient Chamber, National Academy of Sciences, Washington, D.C. (2016)

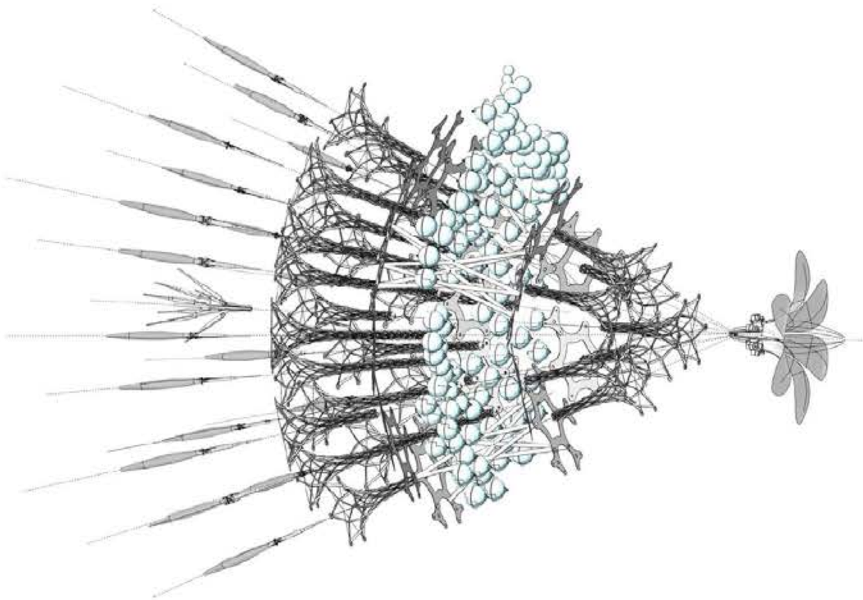


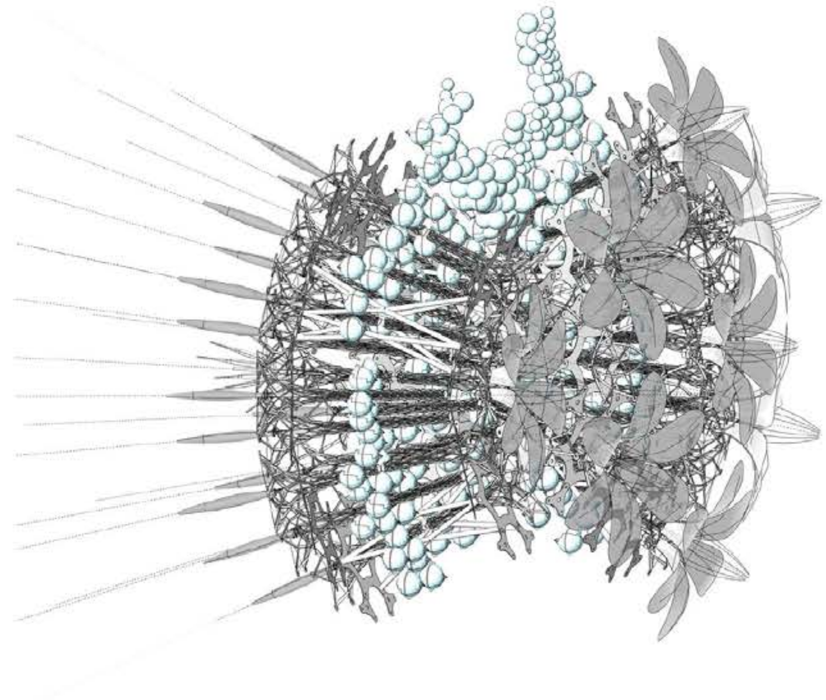


Luddy Hall Installation
Indiana University Bloomington
April 29 2017

UPPER ATRIUM

Philip Beesley • Living Architecture Systems





Amatria Unveiled by Andreas Bueckle et al. Data visualizations of sensor/actuator positions and types, energy and communication flows, and emergent behavior of smart environments.

References

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains.** In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Volume 37, Chapter 5, pp. 179-255. http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf

Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains**. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl_1). http://www.pnas.org/content/vol101/suppl_1

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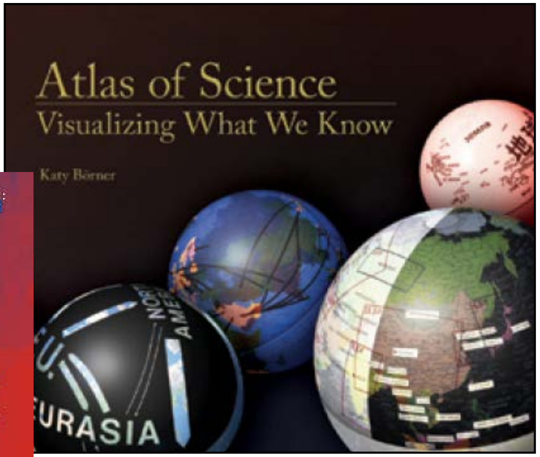
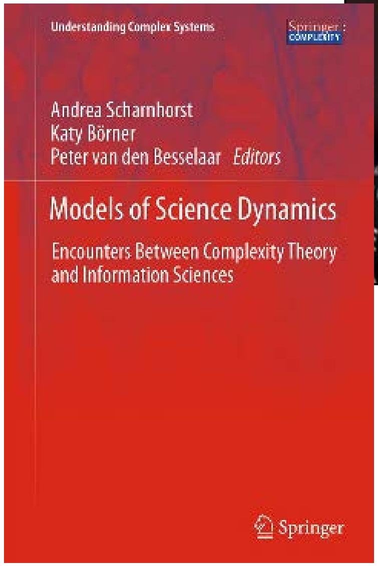
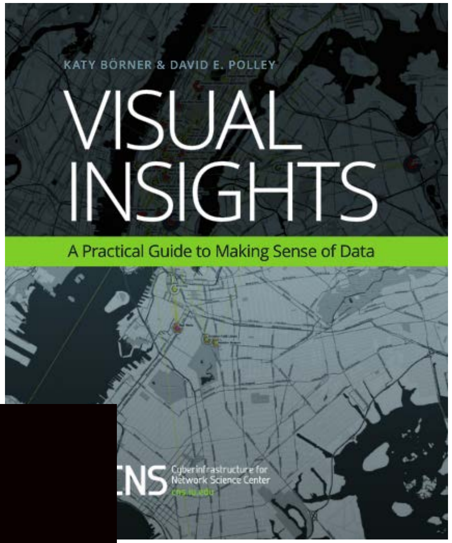
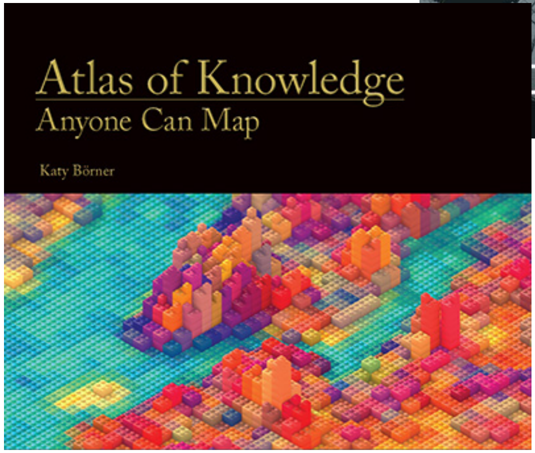
Katy Börner and David E Polley (2014) **Visual Insights: A Practical Guide to Making Sense of Data**. The MIT Press.

Börner, Katy (2015) **Atlas of Knowledge: Anyone Can Map**. The MIT Press. http://scimaps.org/atlas2









All papers, maps, tools, talks, press are linked from http://cns.iu.edu

These slides are at http://cns.iu.edu/presentations.html

CNS Facebook: http://www.facebook.com/cnscenter

Mapping Science Exhibit Facebook: http://www.facebook.com/mappingscience